Cardiac Staging Facility Workflow Redesign

By

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A Senior Project submitted

in partial fulfillment

of the requirements for the degree of

Bachelors of Science in Industrial Engineering

California Polytechnic State University

San Luis Obsipo, CA

June 8, 2010

Graded by: ___________________________ Date of Submission:_____________________

Checked by:___________________________ Approved by:____________________________

Abstract

This study analyzes and proposes Cardiac Staging nurse workflow improvements along with a new Cardiac Staging facility design at French Hospital. Currently, patients spend an expected 125 minutes in Cardiac Staging. It was found that 60% of the time in Cardiac Staging was spent waiting to be transferred into the Cath Lab. The following Industrial Engineering methods were utilized to eliminate waste in staging and design a new staging area:

- Use of Lean and Six-Sigma tools to recommend new patient arrival time
- Manufacturing product scheduling to reduce patient wait time
- Use of facility redesign techniques to improve flow and patient holding capacity

With application of the recommendations, the Cath Lab department can reduce patient waiting time by 75%, decrease scheduling variability, and increase patient holding capacity by up to four times.

Contents

Introduction

The French Hospital Medical Center is a non-profit hospital that has been providing healthcare needs for the community of San Luis Obispo for over 60 years. The French Hospital is currently part of the Catholic Healthcare West (CHW) network which is composed of over 42 hospitals and medical clinics all over California. The mission of CHW is to deliver "compassionate, high quality and affordable care" to its patients. The French Hospital is currently the only hospital that is performing cardiac surgery operations In the San Luis Obispo County.

In 2008, the Cardiovascular Department was recognized as one of the Top 100 Hospitals in the U.S. for performing superior cardiovascular care. In order to ultimately increase patient throughput and improve workflow in their Cardiovascular Department, a location change and facilities layout redesign was proposed for Cardiac Staging. An analysis to improve nurse work flow in conjunction with designing a new facility layout was implemented in order to minimize waste and increase patient holding capacity.

Project Goals

After observing the current system and discussing potential areas to improve with the hospital the project goals were defined as:

- Decrease patient time in system
- Improve Cardiac Staging nurse work flow by identifying and eliminate waste
- Design a new Cardiac Staging layout for improved flow and increase patient holding capacity

Background

The Cardio Department in the French hospital is composed of three sub departments: Interventional Radiology, the Cath Lab, and Non-Invasive. Nurses, Interventionist, Cardiologist, Operating Room Technologist, and other personnel make up the staff in the Cardio Department. On average, the Cardio Department handles 1,200 cases per year. It is important to note however, that the cardiovascular procedures are different from open heart surgeries which are performed in the Surgical Department. Many of the diagnostic and interventional procedures that are performed in Cardio occur in the Cath Lab. Many of these procedures can last anywhere from 30 minutes to 8 hours depending on the complications and difficulty of the procedure. These diagnostic and interventional procedures are done on patients who have coronary heart disease, heart failure, and other cardio-related complications. Most of these procedures are done as elective surgery which is normally performed as an outpatient basis. Sometimes, emergency cases arise from the Intensive Care Unit or the Emergency Department that requires immediate use of the Cath Lab. Even if a scheduled procedure is currently being performed on a patient, if the emergency is severe enough, the current procedure will halt, and the emergency patient will be rushed into the Cath Lab. This stochastic element of the Cath Lab results in a flow of both scheduled and unscheduled patients. A standard flow for scheduled patients for a diagnostic or interventional heart procedure is as follows:

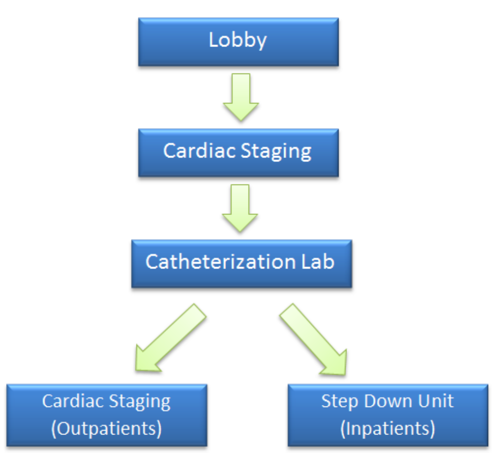


Figure 1 Cath Lab Patient Flow Chart

1. Check in with Front Desk
2. Go to Cardio Staging to be prepped for procedure
3. Proceed to Cath Lab for procedure
4. Return to Cardio Staging for recovery if status is an outpatient
5. Leave Hospital

If patients are not granted status as an “outpatient” by the physician after the procedure, patients will then either proceed to the Step-Down unit or Intensive Care Unit for recovery depending on how close the patient needs to be monitored.

Literature Review

Understanding Modern Healthcare in the 21st century

One the rising challenges for modern healthcare in the 21st century is the ability to provide quality and efficient care that is both affordable and capable to serve patient needs and demand. The healthcare system is also under enormous pressure to curb rising costs while providing not only a high level of quality care but also deliver care in a timely manner that provides greater convenience to the patient (Kobus & Kilment 2000). With an older increasing population in the U.S., hospitals must effectively and efficiently utilize their limited resources to meet patient demand of services and capacities.

Historically, hospitals were not always viewed as the first desirable place to receive care. Since the 1940's and later, home visits by a doctor were much preferred if one could afford it. Hospitals were mainly perceived for patients who were terminally ill or had little hope in recovering from their sickness. Many who could not afford a home visit by a doctor were reluctantly forced to check-in to a hospital (Trimmer 1997). Treating a patient's "sickness" was the main focus for healthcare back then. Patients were only seen by physicians when they had a serious illness or have developed complicated conditions.

Today, a paradigm shift has occurred in modern healthcare, from focusing on a patient's "sickness" to "wellness". If serious health complications or diseases can be prevented or caught early, then the patient has a higher chance of living a higher quality of life. The importance of early intervention and diagnostic services is a result of this paradigm shift. The shift to "wellness" has also resulted how the hospital views itself. Hospitals are now to be seen as "healthy buildings" that promote a higher quality of life and wellness (Miller & Swensson 2002). There have been numerous studies that show that the environment, facility design, and architecture of the hospital impact the health of the patient. The ergonomics of the room, material bed fabric, aesthetics, services, and more - all contribute to the well-being of the patient (Kagioglou 2010). Sadly, many hospital environments that lead to more “unhealthiness” are not uncommon. The phenomenon as “ICU syndrome” is just one example how a hospital environment negatively impacts health. ICU syndrome occurs when a patient in an ICU unit develops hallucinations and a mild psychosis due to the consistent twenty-four hour harsh fluorescent lighting, machine beeping, respirator thumping, and sickly green or stark white walls in the ICU (Miller & Swensson 2002). Hospitals have a responsibility to promote health that should be reflected in its ergonomics and environment.

Furthermore, modern healthcare must be able to adapt to the ongoing changes in medical practices, technology, functionality, and patient demand. To consider all these factors when designing even a small healthcare facility is one of the most complex facility design projects to plan (Perkins 1997). Manual and paper based operations are no longer adequate in today’s modern healthcare. The size and complexity of the system requires a large number of paper and documentation hand-offs from department to department and from physician to physician. Because of this, modern healthcare must use and incorporate technology to their system (Sutherland & Heuvel 2006). In order to manage the size and complexity of the system, hospital managers have begun implementing the Vertical Integration Model. The Vertical Integration Model is a patient focused model that allows many traditional departments to be simplified into a few general integrated areas of responsibility such as: Patient Services, Support Services and Patient Care (Miller & Swensson 2002). This model is able simplify work flow and patient care.

Improving Workflow in the Modern Hospital

The workflow process in the modern hospital is influenced by many different elements such as the facility design and layout, process, staffing, medical procedures, patient demand, public policy, and technology. Each one of these elements has a significant impact on physician and patient workflow.

Studies in Operations Research (OR) whose focus on improving hospital workflow are often met with challenges and problems. Particularly, OR studies who recommend implementation of some new technology to improve workflow are met with cultural resistance and are viewed by the hospital staff as disruptive to current work (Sutherland & Heuvel 2006). The problem of misinterpreting an OR study is also another obstacle. A well-known National Health Services (NHS) OR Study in the UK to improve patient flow was misinterpreted by both hospital managers and policy makers alike. The study reported that when bed occupancy reach around 85%, bed-shortages and work flow problems began to occur. Hospital managers however, interrupted the study that *target* bed occupancy should be at 85%. The misinterpretation in the OR study was due to NHS hospital managers and policy makers craving for only "simplistic answers" and "simple rules", which resulted in vastly oversimplifying the recommendations and misinterpreting data results. Conversely, highly complex OR models fail to implement because of limited application use and non-practicality. (Proudlove 2006). The stochastic nature of hospitals also adds to the challenge to improve workflow. Acquiring estimations of expected utilization and service rates are difficult to predict because of the stochastic nature of arrivals and stochastic movement of patients throughout a hospital. It has been suggested for hospitals to adopt reliable and proven manufacturing production work flow systems to increase their productivity and efficiency. However, hospitals are unable to adopt such work flow processes whose systems are based upon predictable and repetitive document processing. Manufacturing and production systems cannot work with hospitals where standard workflows do not exist (Sutherland & Heuvel 2006).

OR researchers typically have dealt with the stochastic nature of hospital workflows by applying Semi-Markovian models and simulation. Semi-Markov models are capable of providing useful predictions of utilization and capacity constraints in a given stochastic environment (Hershey 1981). They can also be useful for personal staff scheduling and identifying potential relationships among capacities of hospital units. Semi-Markovian models can be an important first step to analyze and forecast resource allocation and capacity planning (Weiss 1982). The next logical step to analyze patient flow is to perform simulation analysis. Simulation's popularity has increased over the years as technology has advanced. Most simulation models have been modeled as discrete-event simulation with the majority of them focusing on patient flow and resource allocation. Discrete simulation has been used to perform sensitivity analysis and forecast impact on patient flows (Jun 1999). Early simulation studies showed the power and benefits of performing simulation analysis. An early study showed an increase patient throughput of 13.4% just by evenly distributing patient demand. (Rising 1973)

In recent years, hospitals have experienced a growth of outpatient appointments due to the demand of diagnostic services and interventional procedures. Facility design and use of technology has to be understood in this context in order to improve workflow. The general considerations for space requirements, operation, and room relationships in each department will all impact patient and physician workflow (Kobus & Kilment 2000). Furthermore, consideration of inter-department work flow emergency situations also needs to be accounted for if a patient needs to be quickly transported from one department to another. For example, the Intense Care Unit (ICU) and the Cath Lab must be easily accessible and located near to each other so that a patient can be moved swiftly and quickly in case of any unforeseen complications (Skaggs 2000). Hospital facilities must also have the capacity to be flexible to accommodate changing technology and current hospital model trends. The Vertical Integration Model is changing how hospitals are organizing their departments and patient flow throughout the hospital system. Sadly navigation through hospitals are said to be one of the most confusing places to navigate through. This is partly due to hospital labels using unfamiliar terminology to the public like "Otorhinolaryngology" (Janet & Grant 1997). Numerous studies have shown that the design of hospital facilities also has an impact on medical care on the patient. It's been studied that the environment, ergonomics, presentation, and aesthetics of a room, all impact the health of the patient. For example, if a room is well lit, "healthy looking", with a window that has a view of green grass and a water fountain, the patient will have a positive impact and gain “positive energy” to start their healing process (Kagioglou 2010). In addition, facilities also impact staff productivity as well. Imagine if a hospital were cold, dark, dim and damp with narrow corridors and no windows. Obviously, work productivity would decrease due to the gloominess, and unwanted work conditions (Trimmer 1997). All these impacts and effects of facility design on the patient and staff eventually affect the workflow in a hospital.

The stochastic nature of hospitals also demands that the hospital must be able to adapt and react to demands in patient capacity and urgency quickly. OR studies in technology that have tracked patient and resource utilization have better workflow adaptability both for the patient and physician. A study done by the University of Maryland Medical System sought to incorporate a total “situational awareness” technology system that is able to track patient location, capture live data, plan needed supplies, handle patient documentation and be fully aware of current system bottlenecks . The system was able to monitor and improve throughput while enhancing patient safety and patient care. The application of RFID was used to track patient location and capture data. The study reported a 100% improvement in supply and instrument readiness as well as increase throughput (Sutherland & Heuvel 2006).

The ability of a hospital to manage patient flow in a hospital is another crucial component of improving workflow. One of the challenges to manage patient flow is due to fluxuations of patient demand. One way to manage patient demand is by managing patient variability. There are two types of patient variability that have been identified that contribute to fluxuations of patient demand: natural variability and artificial variability. All patients who are admitted at the hospital naturally have different severity of diseases, arrival times, and different physician quality of care. All these attributes are natural variables and can be only optimally managed. Artificial variability however, is “nonrandom, nonpredictable, and driven by individual priorities”. Artificial variability should be reduced and eliminated. Hospitals currently do manage natural variability instinctively, but not scientifically. For example, hospitals divide floors and departments by homogenous conditions. Hospital managers who seek to improve patient throughput by managing patient flow often use metrics that are not helpful. The three most common metrics used to increase patient throughput (high hospital unit occupancy rates, high utilization rates, and reduction in time for patient transfers) do not guarantee maximizing patient throughput or even leads to the right means of maximizing throughput. Instead, in order to maximize patient throughput, one must manage patient variability in the hospital system. (Litvak 2005).

Data Collection for Workflow Redesign

Design

One of the first tasks to a workflow redesign of any process is to first understand the current state of the system. This involved a combination of observations and discussions with patients, hospital staff, and management. Patients were observed going through the entire process from beginning to end in order to understand the current flow. In Cardiac Staging, the nurse work flow for pre-procedures was observed in order to gain insight of what key data points to collect. By observing both patient flow and nurse work flow and receiving input from key stakeholders, it was determined that there would be two categorical data sets. The first set of key data points would consists of an overall system overview of:

- Patient Staging Duration
- Procedure Duration
- Patient Recovery Duration

The second set of data would consist of a more detailed analysis of the nurse work flow in staging. The observed nurse workflow for pre-procedure in Cardiac Staging can be divided into four different phases: Admitting, Assessment, Preparation, and Transfer Phase. Each of these phases would be a data point in the second data set. Figure 2 lists each phrase with a short description.

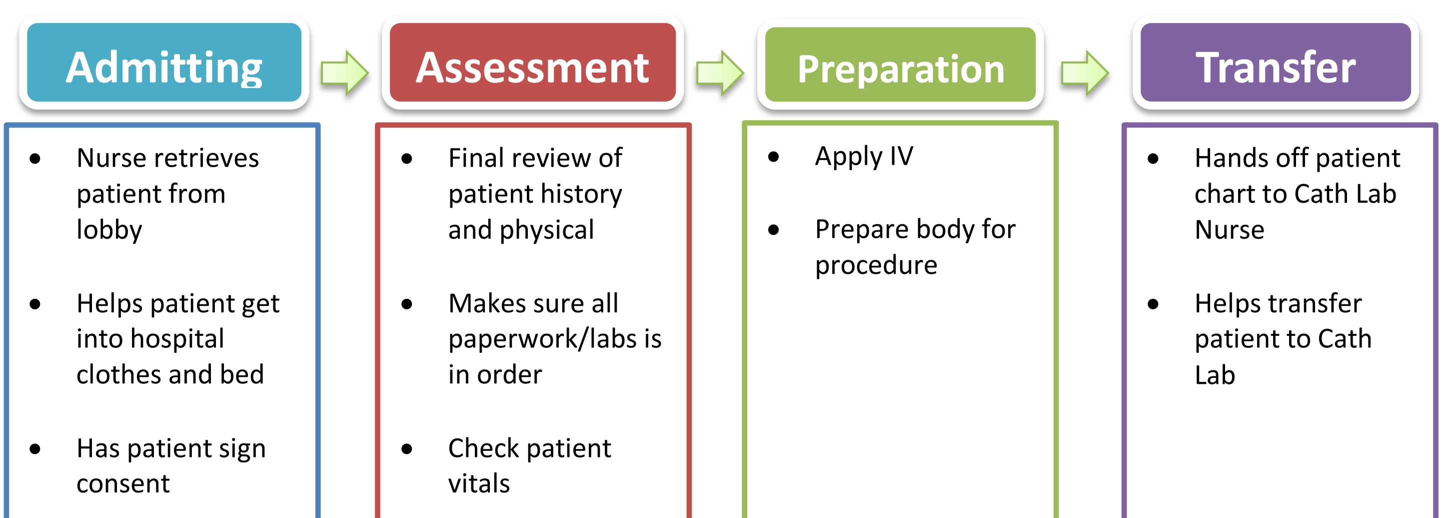


Figure 2 Cardiac Staging Nurse Workflow

Observed Nurse Workflow Variability

It must be also noted that there are two primary types of patients that go through Cardiac Staging: Cardio and Interventional Radiology (IR) patients. The nurse workflow for each of the two types of patients share many similarities, but there are differences. Many of those differences lie in the preparation and transfer phase. For instance, usually IR patients are visited by their doctors to go over the procedure right before the transfer phase while cardio patients do not. For a more detailed breakdown of the different phases according to patient type see Appendix A and B.

Additionally both the assessment and preparation phase can also be executed simultaneously and not necessary in sequential order. For instance, when the nurse goes and retrieves the patient from the lobby the nurse may began the assessment phase before the patient even reaches the staging area. The procedural details of each phase may necessary change depending on the patient. Figure 2 (see above) is a general nurse workflow in Cardiac Staging and is not meant to capture every workflow variation that occurs.

Methodology

System Overview Data

Currently the hospital keeps track of staging and recovery duration data by manual paper based recording while procedure duration time is kept in an electronic log. In the beginning of this study there was no statistically compilation of data for any of the data points. It was decided given the many different types of procedures done, following a handful of patients through the entire system would not statistically accurately reflect the system. Therefore, patients who have gone through the system who were recorded in both the manual and electronic log for the past three months would be complied. The manual log just recently started in January and three months was the farthest back in time possible to collect data. The data collected only reflects day-shift outpatients. Not every patient was able to be recorded due to missing data points in the manual log, and therefore the data collected **should not** be used as a total volume number of day-shift outpatients seen by the Cath Lab between the months of January to March.

Staging Data

Time studies were applied to each phase following one nurse at a time. Staging nurses were very helpful in explaining their current procedures and general observations began in order to identify key points in each phase in which to record data. Nurses were informed regarding the purpose of the time study and that the study was measuring the work and not the individual. Continuous time study methodology was utilized and a Traceable Decimal Stopwatch was used. A total of twelve cases were recorded in detail.

Results

System Overview Data

A total of 246 cases were captured in the manual and electronic log. The case type breakdown was 190 Cardio cases to 56 IR cases. It was found that procedure and recovery duration should be characterized as an interval rather than a single data point given the many different types of procedures and necessary recovery times depending on a given procedure. Table 3 is a summary of the data collected. (Note: If the data distribution was not normal, the median time was taken instead of the mean)

Staging	Procedure	Recovery
125 min	(65min – 240 min)	(70 min – 200 min)

Table 1 System Overall Data

Patient Staging Duration

This study found no statistical difference in the average staging duration time between Cardio patients compared to IR patients (See Appendix C). Despite the variability and differences in the nurse workflow, both types of patients can expect to spend the same amount of time in Cardiac Staging. Figure 3 shows that the statistical distribution is skewed right, indicating that the majority of the patients fall within a 115-135 minute median range with remaining outliers skewed to the right.

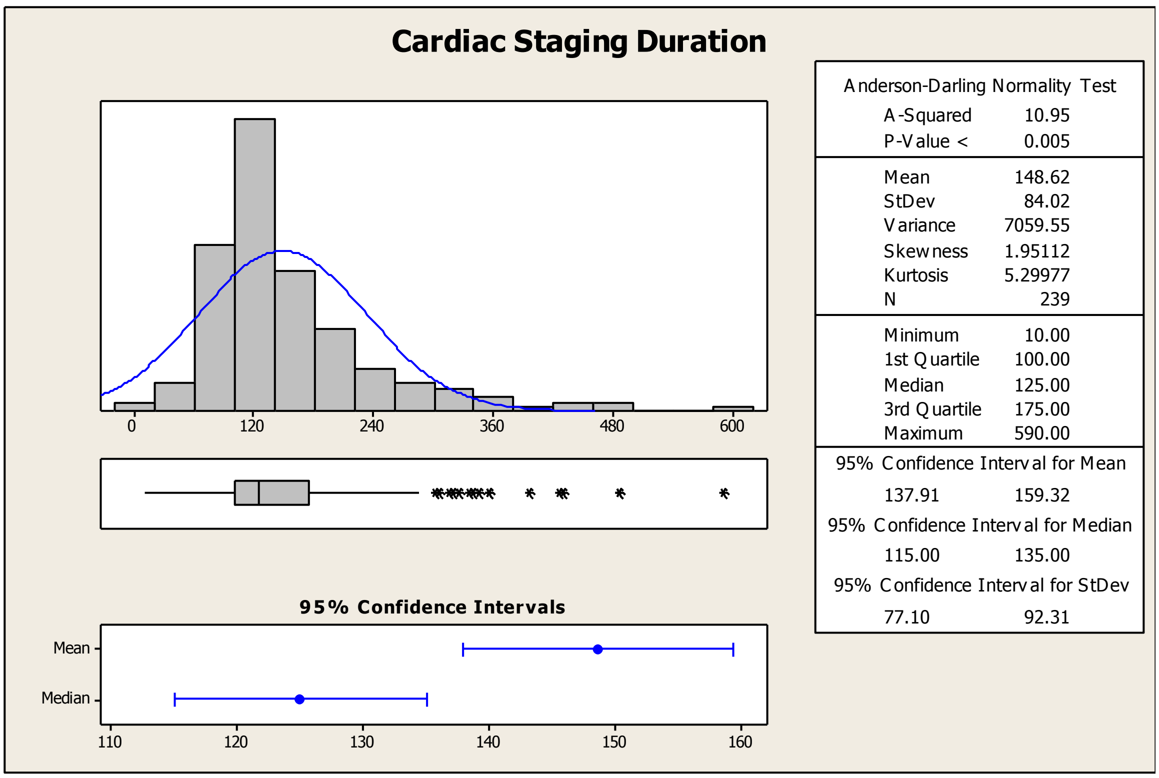


Figure 3 Cardiac Staging Duration

Procedure Duration

A total of 27 different procedures were captured in the study. (See Appendix D for complete statistical data for each procedure). The different types of procedures can be characterized by their type (Cardio or IR) and their category (Cardiac Pacer, Cardio Invasive, Cardio Non-Invasive, IR Procedures). A two sample T-test was conducted to determine if Cardio procedures took longer than IR procedures. The T-test p-value was found to be 0.000 indicating that Cardiac procedures take statistically longer than IR procedures. When the sample size of a procedure was less than 5, one of the Cath Lab managers was consulted on the validity of the data in order to preserve its accuracy. The following charts are a breakdown of the different procedure types and categories by duration.

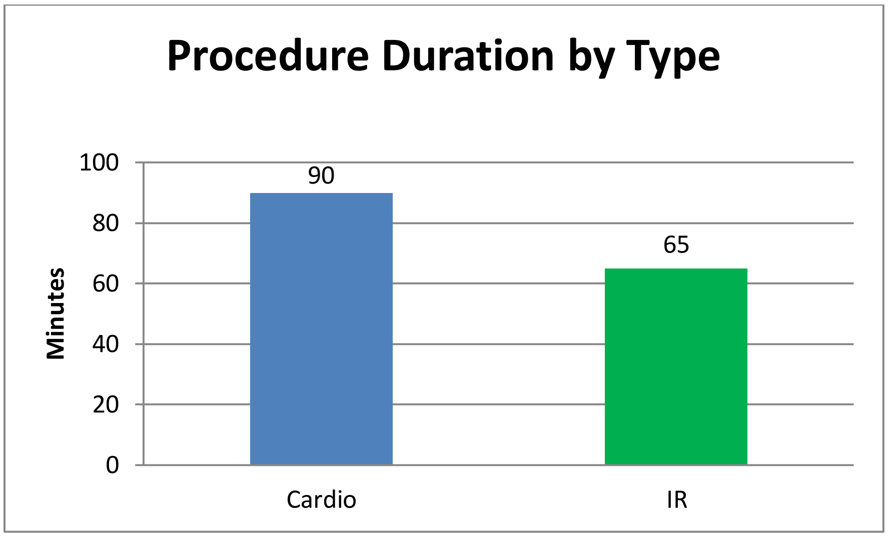


Figure 4 Procedure Duration by Type

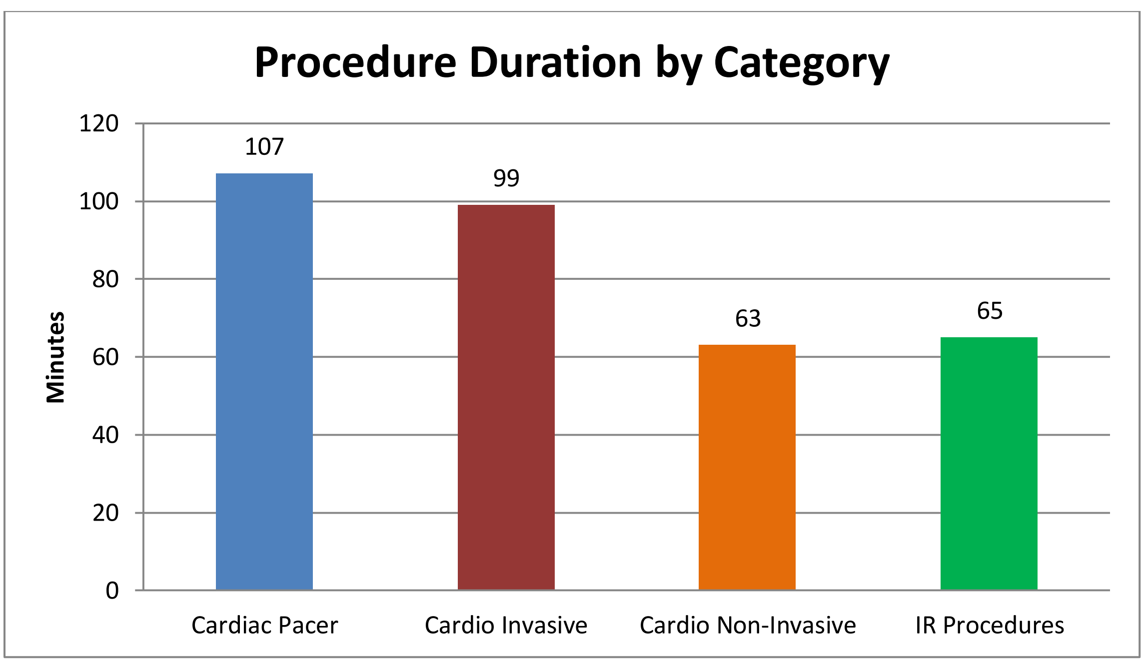


Figure 5 Procedure Duration by Category

Recovery Duration

The time of recovery depends on several factors. The first factor is a time requirement by the State of California for how long a patient must stay in the recovery area regardless of how well a patient feels after the procedure. The second factor depends on the type of procedure performed on the patient. Less complicated procedures usually resulted in a short recovery period than a longer and complicated procedure. For a complete recovery statistical breakdown by each procedure see Appendix E. This study found that Cardiac patients stay in recovery statistically longer than IR patients in the recovery area. Figures 6 and 7 on the next page illustrates the recovery duration by type of procedure and category.

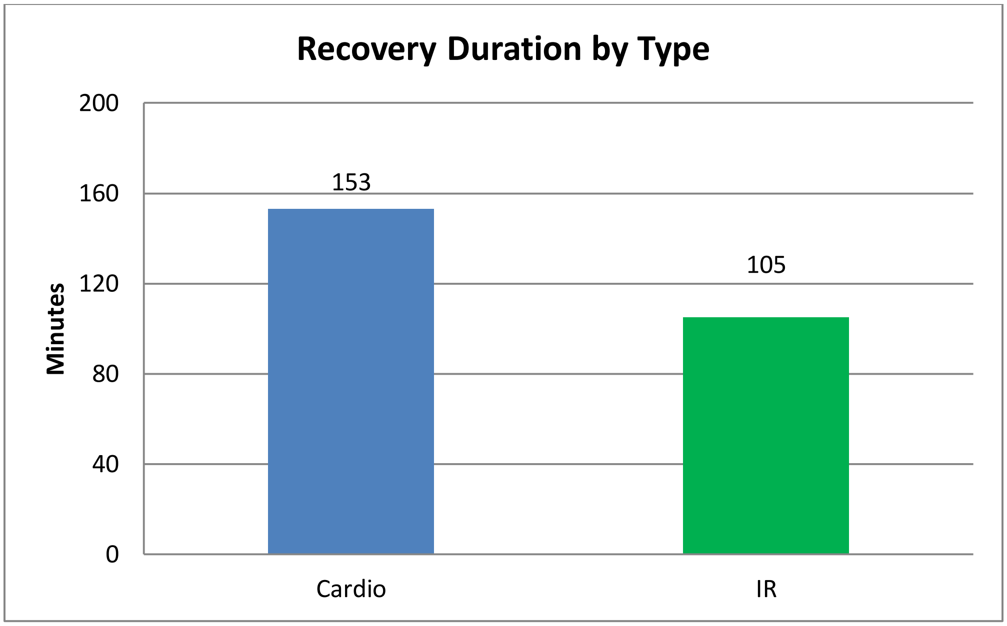


Figure 6 Recovery Duration by Type

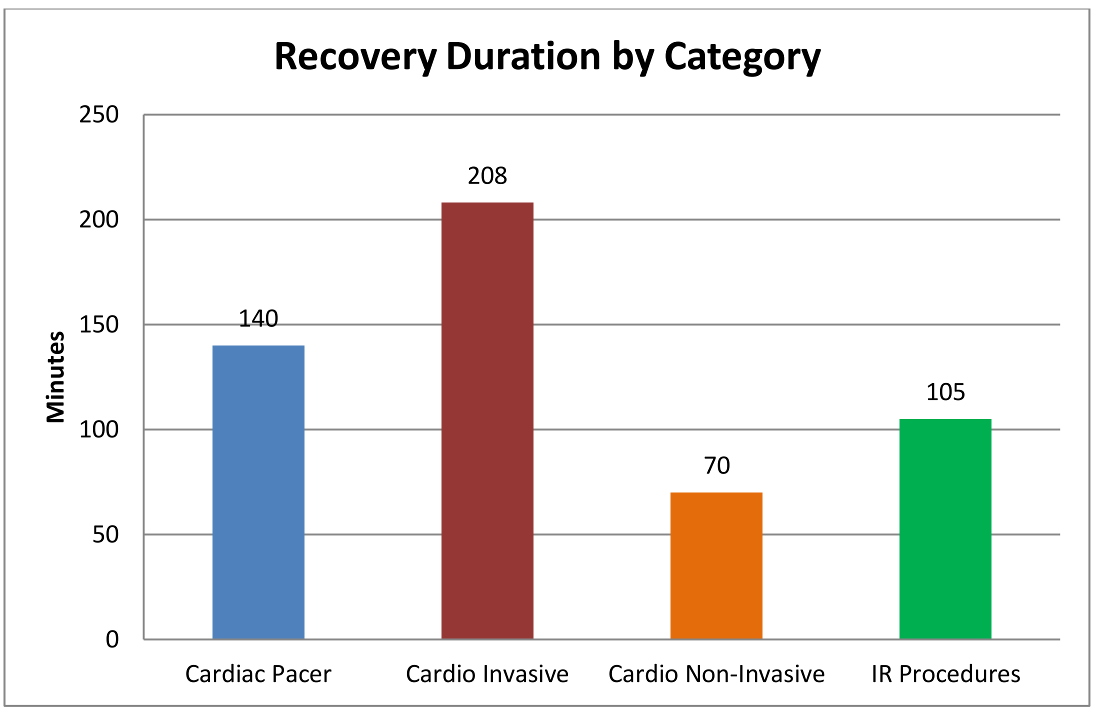


Figure 7 Recovery Duration by Category

Staging Data

Twelve cases were followed overall in detail through Cardiac Staging. Figure 8 is a summary of the time studies in each phase. See Appendix F for each time study case in detail.

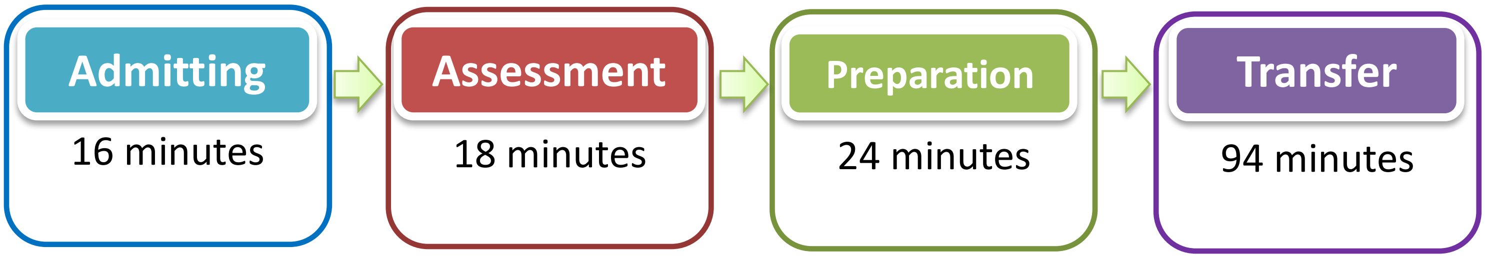


Figure 8 Nurse Workflow Time Study Results

While the Admitting, Assessment, and Preparation phases took relativity the same period of time, the length of the Transfer phase was observed to be comparatively longer than the other three phases. This seemed very unusual since the transfer phrase has only two major components. (See Appendix A and B for a detailed breakdown for each phase).

Value Stream Map Analysis

A Value Stream Map (VSM) was designed in order to identify non-value added time for a closer analysis in the nurse workflow. A Value Stream Map is a Lean tool used to identify waste in a process. In this context, non-valued added time was regarded as any movement or work done that did not increase the quality of the patient's procedure. See Appendix G for the complete current VSM diagram. Figure 9 portrays the value added time in a Lead Time chart.

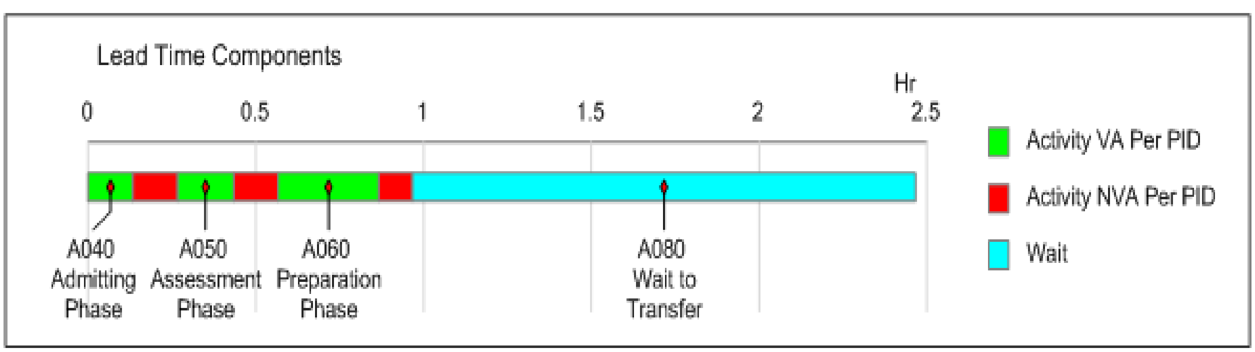


Figure 9 Current Lead Time VSM for Nurse Workflow

It was observed that much of the non-value added time during the Admitting, Assessment, and Preparation phase turned out to be necessary non-value added time. For instance, the State of California requires nurses to repeat and record certain information of the patient regardless if the information was accurate the first time. Repeating correct information was deemed non-value added, however it is mandated by the state and therefore it is considered a necessary non-value added time. The majority of the non-value added time was observed in the Transfer phase. Waiting to transfer took 90 minutes out of the total 94 minutes during the Transfer phase. A breakdown of the total time spent in Cardiac Staging is shown in Figure 10 which demonstrates that out of all the time spent in Cardiac Staging, 60% of the time is spent waiting to transfer.

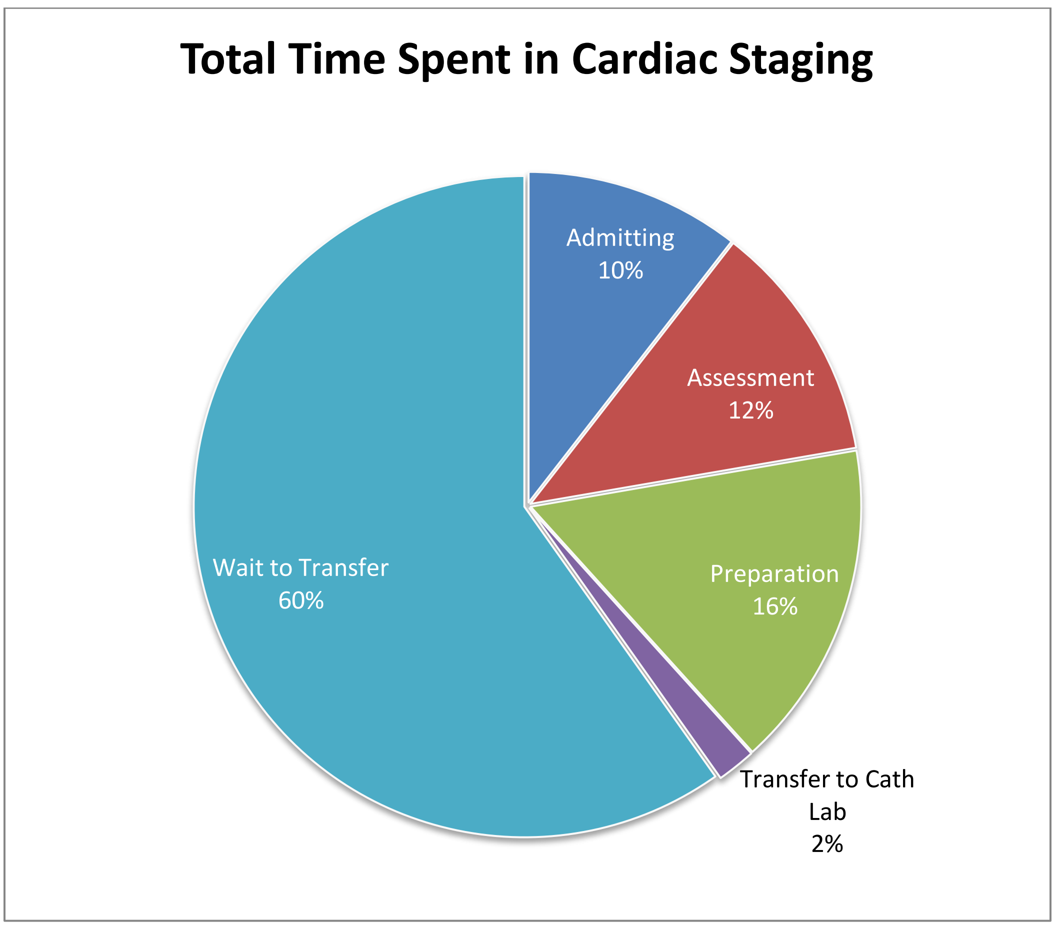


Figure 10 Breakdown of time spent in Staging

Eliminating Waste and Decreasing Patient Waiting Time

Design

The Value Stream analysis in Cardiac Staging revealed that the largest amount of non-value added time are patients waiting to transfer into the Cath Lab. The time data collected in Cardiac Staging also revealed that the Admitting, Assessment, Preparation, and Transfer phases without waiting time takes approximately one hour to complete. Currently the expected duration that patients spend in Cardiac Staging is around 124 minutes. This means there is a considerable amount of patient waiting or queue time for the Cath Lab room. The time waiting to transfer is the largest amount of waste and reducing the waiting time would yield the biggest benefit to decrease patient waiting time in Cardiac Staging and eliminating non-value time in the workflow.

Cause and Effect Diagram

To determine the root cause of why patients where waiting so long a Cause and Effects diagram was developed. The design of the Cause and Effect digram was based upon direct observations and discussions with the Cardiac Staging nurses and Cath Lab manager. See Figure 11.

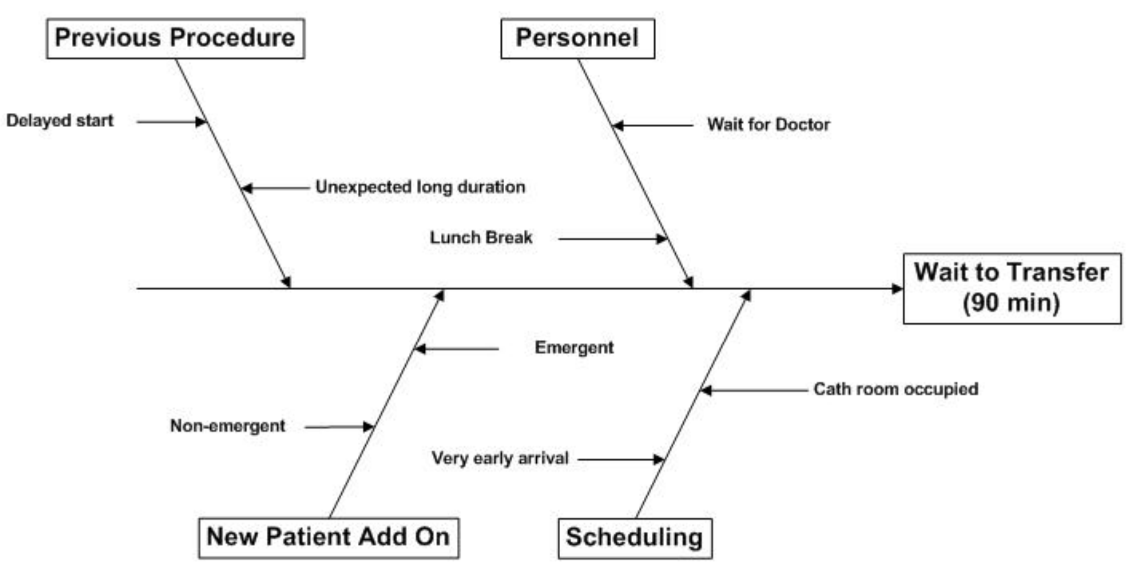


Figure 11 Cause and Effect Diagram

From direct observations and input from the hospital staff, four major areas of possible causes were identified for the 90 minute waiting to transfer that was observed from the time studies.

Previous Procedure-If the previous procedure had a delayed start or if complications arose which resulted in a longer unexpected duration, the patient who is in queue for the Cath Lab will have to wait longer. Unexpected long durations are not uncommon because there are many unforeseen variables that can only be discovered once the procedure is underway.

New Patient Add On-A new patient may be added onto the schedule because of emergency or convenience ahead of an already queued patient which results in a longer wait time for the patient who was currently next.

Personnel-For a procedure to begin in the Cath Lab, all necessary personnel must be present. Waiting for doctors to arrive to the Cath Lab or the Cath Lab staff taking a lunch break can result in delaying a procedure.

Scheduling-Patients who come in to be prepped very early either by direction or voluntary can result in a long wait time. The general scheduling guideline that was observed was for a patient to come in two hours before their expected scheduled procedure. Exceptions to the guideline included the type of procedure and time of day the expected schedule procedure would start.

After observing Cardiac Staging and receiving input from the hospital staff, the major category that was identified to contribute to long queue time with the most impact and consistency was in the category of scheduling. Scheduling contributed to long wait times due to the Cath Lab room being occupied regardless if the previous procedure started and ended on time. The other possible major categories were discovered to be either unavoidable (such as emergencies) or have minimal impact due to infrequency.

Reducing Patient Waiting Time by Scheduling

Reduce Patient Arrival Time before Procedure

Reducing the time of arrival before the scheduled procedure can reduce the time waiting to transfer. The reason for early arrival is that the Cath Lab and staff should not be idle and waiting for the patient to be done prepping in Cardiac Staging. It is important to understand that patients need time to prepare themselves mentally and feel comfortable before the procedure. Therefore, some waiting time can be viewed as beneficial to the patient. However, extreme long wait times can contribute to patient dissatisfaction of the quality of the service. These considerations will be translated to a 20% buffer time in addition to the one hour expected preparation time.

Shortest Processing Rule (SPR)

The shortest processing rule is a scheduling rule used by manufacturing managers in order to reduce queue time for products waiting to be processed at a workstation. The rule states that in order to minimize waiting time for all products, the product that has the shortest processing time should be scheduled first. This means that the scheduling sequence of products should be in the order from shortest to longest in terms of their processing time for a given workstation.

In the context of Cath Lab procedures, this means patients should be scheduled from shortest to longest in terms of expected procedure duration in order to decrease overall patient waiting time. It must also be realized however, that even within the same type of procedure duration variability occurs. Some procedures have greater variability than others depending on the complexity of the procedure. Therefore, variability must be accounted for because unlike manufacturing where products are predictable and the same, human beings are not.

Methodology

Reduce Patient Arrival Time

It was found that it takes approximately one hour for a nurse to complete prepping a patient in Cardiac Staging. Therefore, any staging duration over an hour can be reasonably assumed that the patient was waiting in Cardiac Staging to be transferred. It was found that out of 229 cases captured in the study, 226 cases had a staging duration above an hour. This results to 95% of cases having to wait. The 20% buffer time including staging preparation time resulted in a total expected cardiac duration time of 72 minutes.

Procedure Prioritization by using SPR

To determine how procedures should be prioritized, two metrics were applied: 1.) Procedure duration and 2.) Variability. The median time was used for procedure duration instead of the mean, since procedure distributions were not normal. Variability was determined by the range of one standard deviation of the procedure. Tables 2 and 3 show how procedures were categorized by duration and variability. For example a cardioversion has a priority of 1B.

Table 2 Procedure Prioritization by Duration

Priority Number	Procedure Duration (hrs)
I	0-1
2	1-1.5
3	1.5-2
4	2-2.5
5	2.5+

Table 3 Procedure Prioritization by Variability

Type	Std. Dev (min)
A	0-15
B	15-30
C	30+
X	Unknown

See Appendix I for complete list of procedures and their priority.

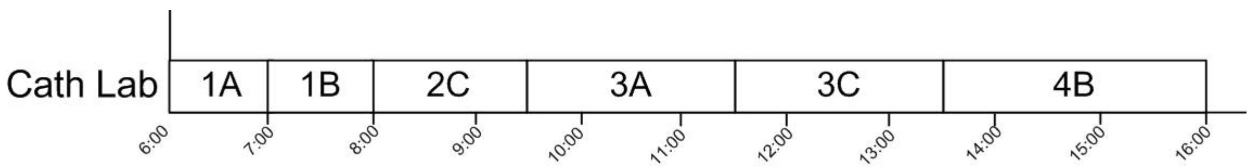
Scheduling with Procedure Priority

The task to determine which procedure to be scheduled first is a two-step process.

1. Procedures that have highest priority number (1 = highest, 5 = lowest) should be scheduled first (shortest procedure duration).
2. If there are multiple procedures of the same number, then schedule the procedures by starting alphabet first (lowest standard deviation).

Figure 12 below is an example of how procedures should be scheduled using the SPR. Notice when there are multiples of the same priority number, then the procedure with highest starting alphabet is first.

Figure 12 Scheduling with Priority Example



Results

Reduce Patient Arrival Time

With the current general guideline of patient arrival time of two hours before procedure, it was found that the actual preparation time needed with a 20% buffer is 72 minutes. Thus is it advised that patient arrival time before a Cath lab procedure should be reduced from two hours to an hour and fifteen minutes. This will reduce current waiting time from 60 minutes to 15 minutes. See Appendix H for the new proposed Value Stream Map of the nurse workflow. Figure 13 portrays the reduction of non-value added time.

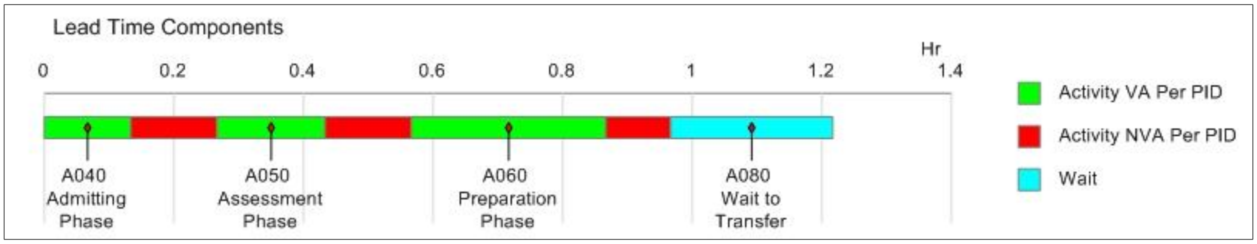


Figure 13 Proposed Lead Time VSM for Nurse Workflow

Scheduling with Procedure Priority

Before Applying SPR

The ability to reduce overall queue time by using the shortest processing rule can be demonstrated with a real case example. On February 8th for Cath Lab 2, four patients were scheduled with four different types of procedures. The total waiting time patients had to wait was 540 minutes, which translates an average wait time of 134 minutes per patient. See Figure 15 on the next page.

After Applying SPR

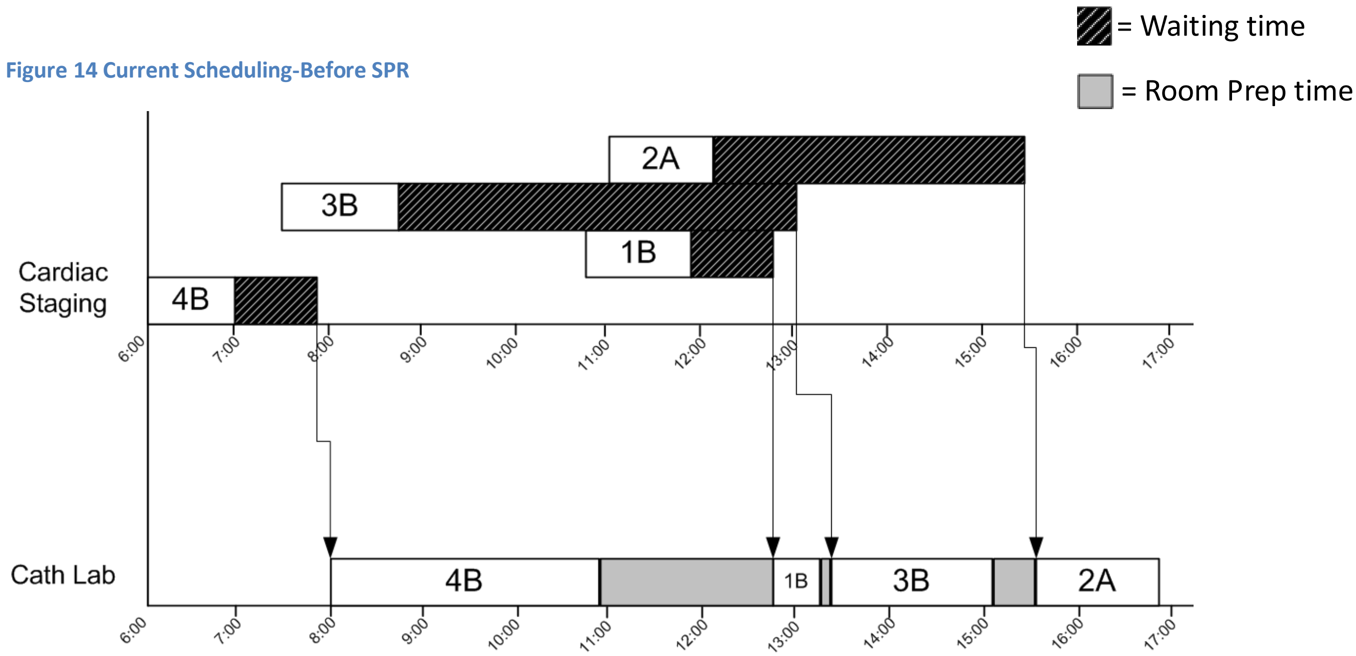
In keeping with the current patient scheduling time and procedure duration times that did occur on Feburary 8th, by rescheduling patients by the SPR, the total wait time decreased to 195 minutes with an average wait time of 49 minutes. Patients 3B and 2A saw the most decrease in waiting time. A total of 345 wait time minutes with an average of 84 minutes was eliminated. See Figure 16 on the next page.

The SPR is most effective when three or more patients are scheduled that have different numerical priority numbers. If all patients have the same numerical priority number, then the effect would be minimal.

Summary of the two schedule recommends are:

- Have patients arrive one hour and fifteen minutes before procedure
- Apply SPR to scheduling

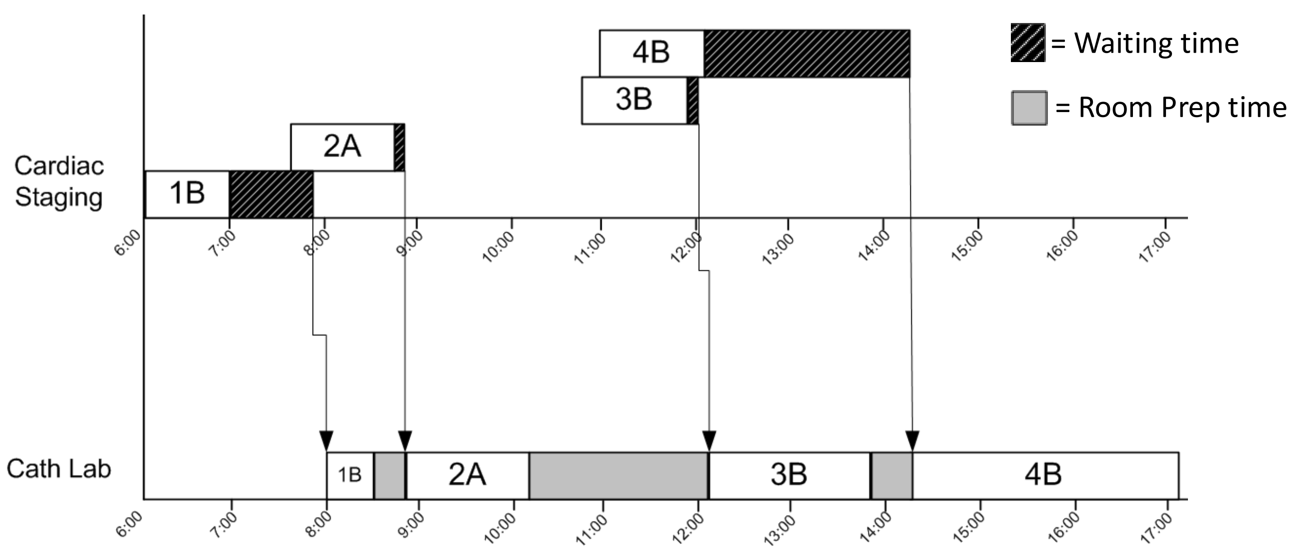
Figure 14 Current Scheduling-Before SPR



Total Waiting Time = **300 minutes**

Average Wait Time Per Patient = **134 minutes**

Figure 15 Proposed Scheduling-After SPR



Total Waiting Time = **194 minutes**

Average Wait Time Per Patient = **49 minutes**

Facility Workflow Redesign

The Systematic Layout Facility approach was used to design the new Cardiac Staging facility. The approach has 5 sequential steps:

1. **Input process**-Collect and understand all relevant data regarding the facility. Understand current process flow and operations.
2. **Relationships**-Understand relationships (both quantitative and qualitative) between departments and within departments.
3. **Space Requirements**- Understand new facility space and current space usage.
4. **Develop Alternative Layouts**
5. **Recommend Design**

The goal of the new Cardiac Staging facility was to increase patient holding capacity and minimize nurse movement.

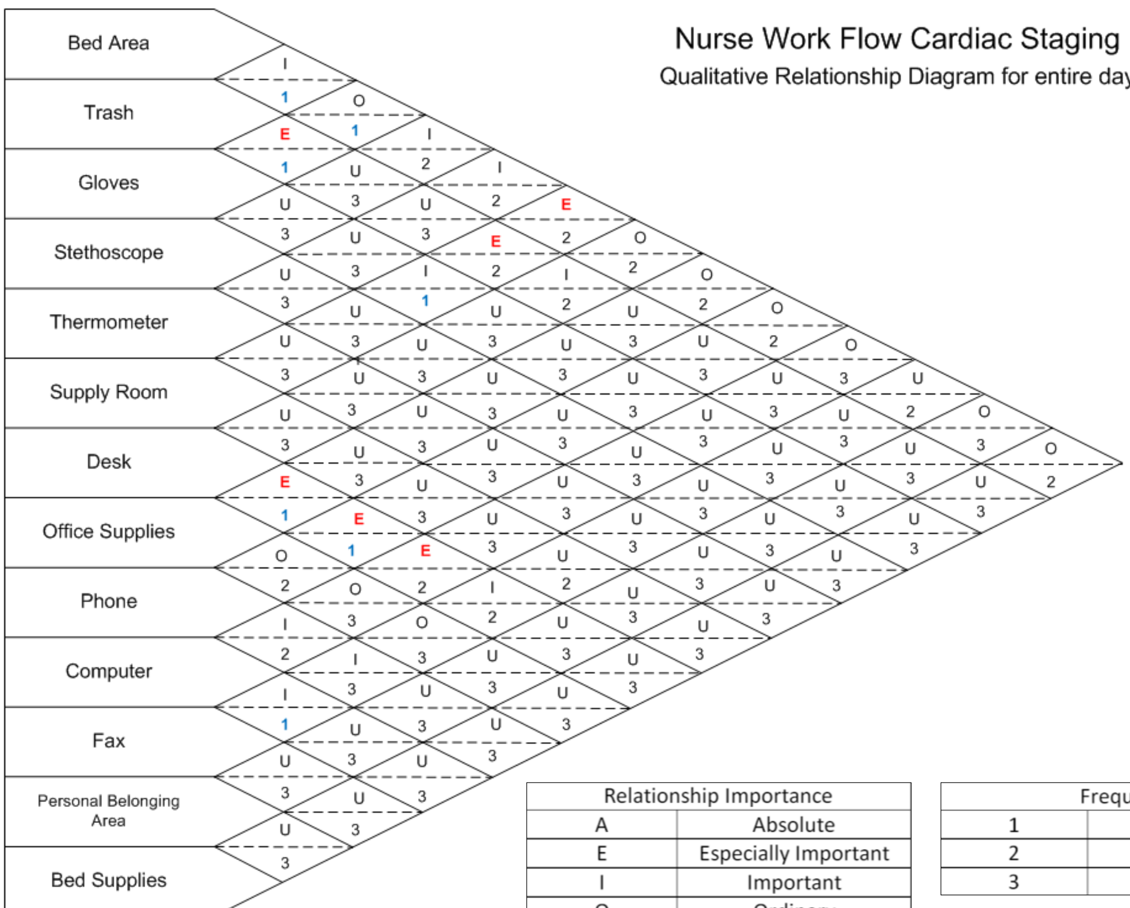
Input Process

Understanding current process flow and operations in Cardiac Staging was gathered by observations and time studies conducted in the beginning of this study. Necessary equipment and materials used was also observed in the nurse workflow. In addition to quantified data collected in the beginning of the study, several qualitative aspects of the current layout were observed and discussed by staging nurses. Several prominent qualitative concerns about the current facility were:

- Patient curtains do not entirely block out outside view, exposing privacy
- Current spacing between beds and nurse desk is cramped
- Overcrowding in staging area easily occurs due to restricted space
- Nurse workflow interruptions can be minimized by better communication channels between staging nurses, doctors, and Cath Lab nurses.

Relationships

Using information gathered from all the input process, a relationship diagram was generated. A relationship diagram shows the strength of the relationship between areas or objects, indicating how necessary the location should be near to each other. A quantitate relationship chart was first generated for the nurse workflow preparing a patient. (See Appendix J). From the quantitative relationship chart and discussions with Cardiac Staging nurses, a qualitative relationship chart was generated for nurse workflow for an entire day. See Figure 16 below.



Relationship Importance	
A	Absolute
E	Especially Important
I	Important
O	Ordinary
U	Unimportant

Frequency	
1	Frequent
2	Fairly Frequent
3	Not Frequent

Figure 16 Nurse Workflow Qualitative Relationship

Space Requirements

The current staging facility has the capacity of four beds, a small nurse desk, and a supply room. The restricted small space is due to the original room design for an X-ray room. The present state of the facility allows for overcrowding frequently and it is not uncommon for holding capacity to be surpassed. In order to increase capacity to handle increase patient throughput, a new staging facility was proposed. Figure 17 shows the current staging facility.

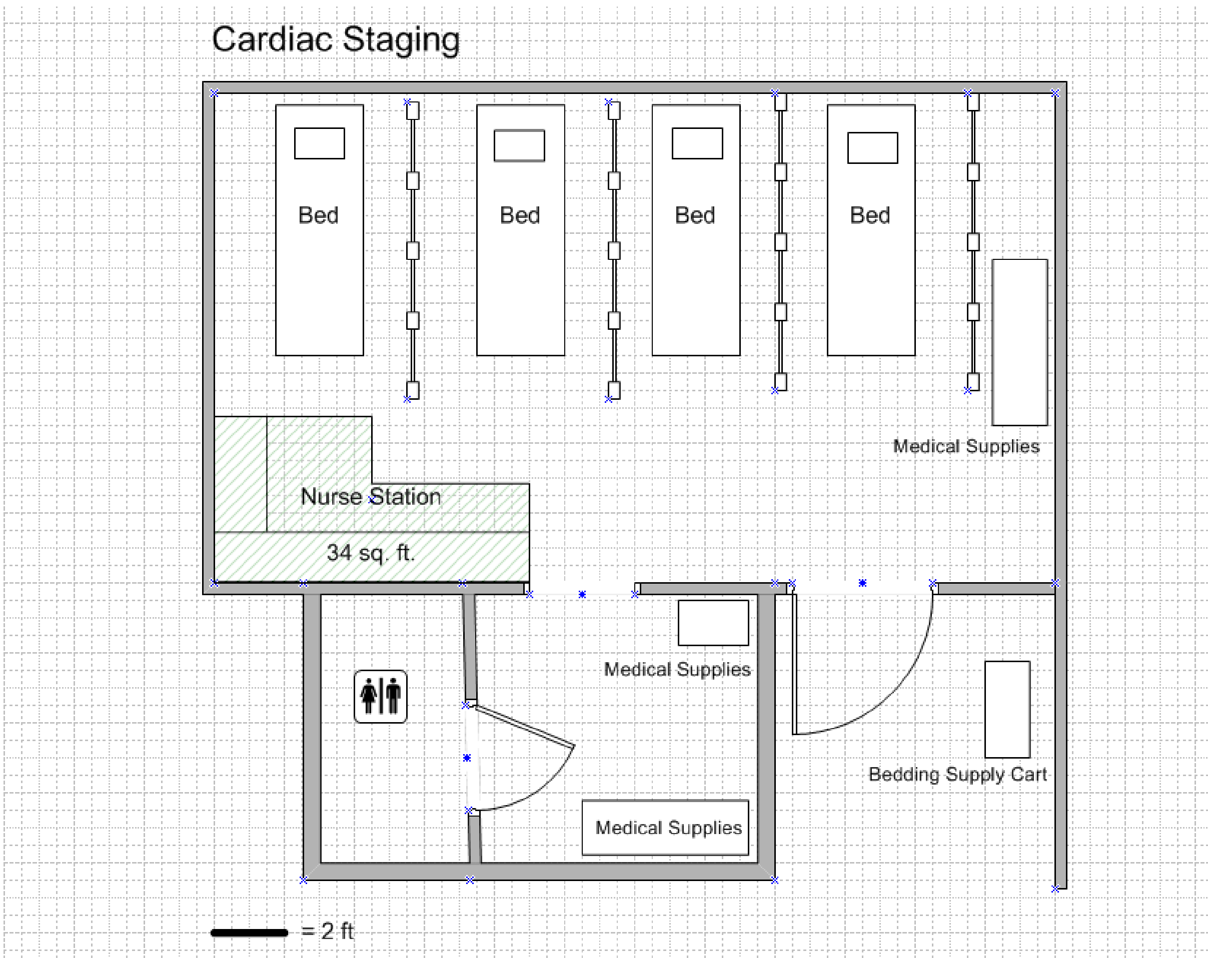
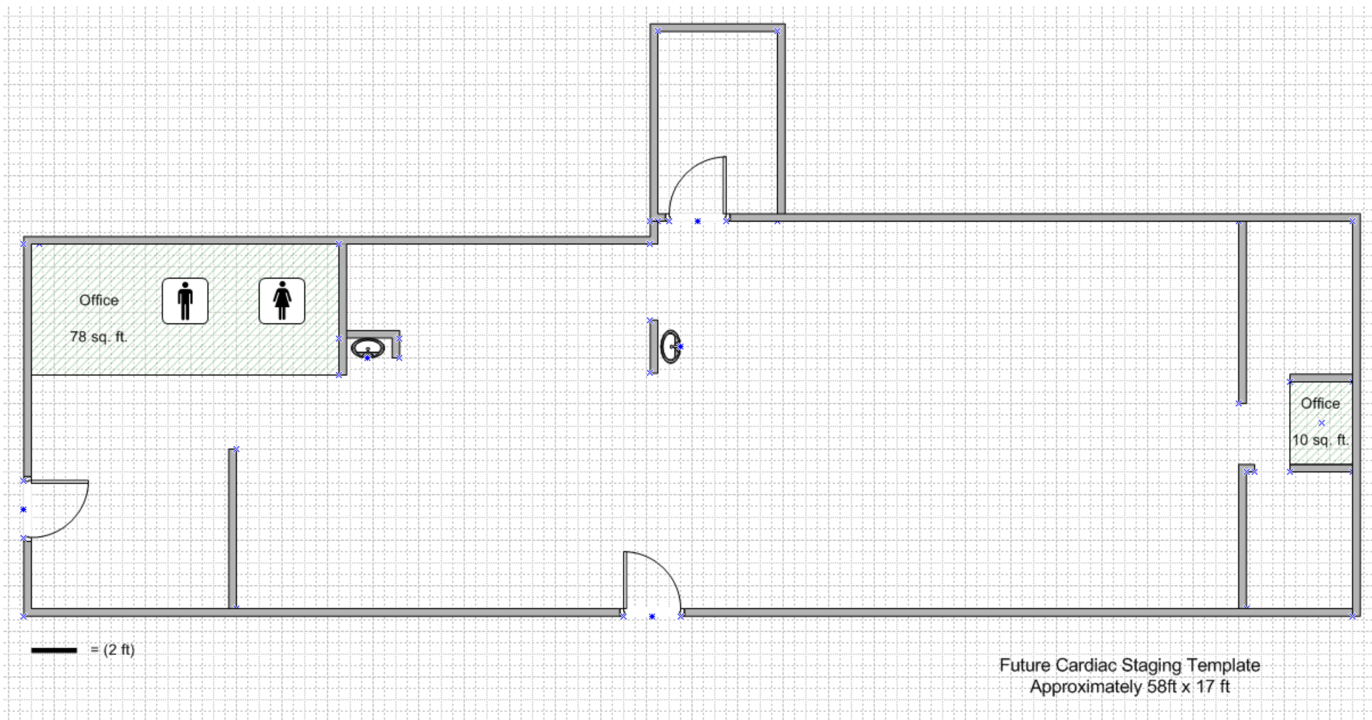


Figure 17 Current Cardiac Staging

The proposed staging facility space requirement was given. The new staging facility is projected to be almost four times larger than the current facility. The new facility will include an expanded nurse station, more available space for patients, more sinks, and more space for computer workstations. A template was given to use as the starting design.

Figure 18 New Staging Template



Alternative Layout 1: Maximize Bed Capacity

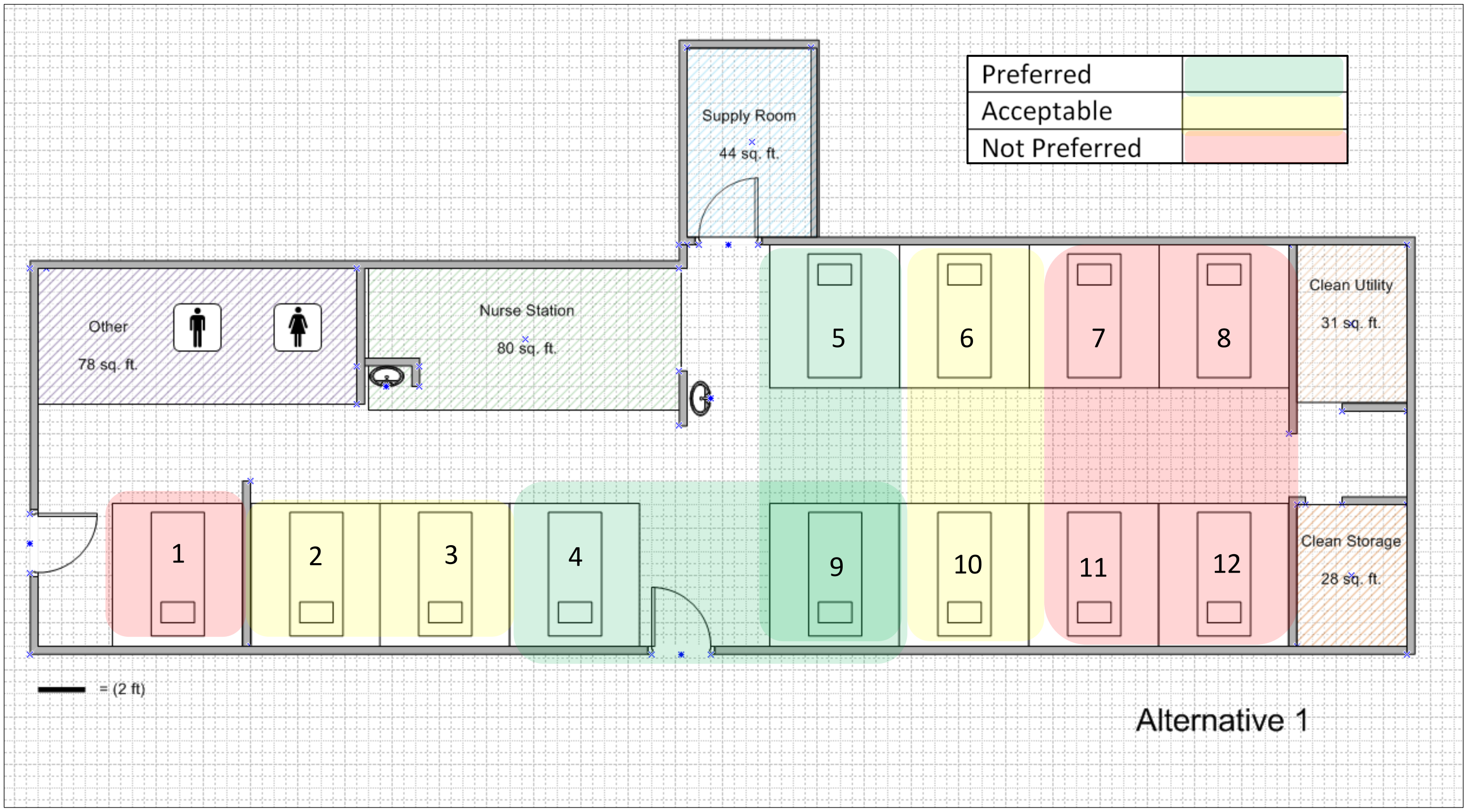


Figure 19 Alternative Layout- Maximize Bed Capacity

This layout seeks to utilize all available space with beds. This layout can hold up to 12 beds and does not designate any specific space or bed for pre-procedure or post recovery. The preferred bed space area is designated to be near the nurse workstation and supply room. The nurse workflow movement is minimized by attending a patient in the green preferred bed space area. Yellow signifies increase movement and red is the farthest and least preferable.

Expected Workflow Distance

Nurse workflow movement will be calculated by bed position #6. This position was chosen because it's moderate preference and ability to reflect average workflow distance. Distance was calculated from data gathered from the relationship diagram. The expected distance for nurses to travel on a given patient is approximately 574 feet.

Cost Analysis of Workflow Movement

Cost was calculated by movement and nurse hourly wage with the assumption that a nurse walks 3 mph. Daily cost and yearly cost was then calculated by the average number of patients per day or patients seen in an entire year. See Appendix K for detailed movement and cost calculation.

Table 4 Alternative 1 Cost Workflow Movement Analysis

Movement per patient	574 ft
Nurse hourly wage	$35
Estimate Daily Cost	$26
Estimate Yearly Cost	$6,800

Qualitative Analysis

Strengths

The capacity of 12 beds results in a 200% increase capacity compared the current staging capacity of 4 beds. This increase of capacity will also decrease the chance that the holding capacity will not overflow. Also since there is no designated pre-procedure or post recovery area, this allows flexibility for workflow of the nurses. This layout is a balance workflow design between attending patients who are preparing to enter procedure and recovery patients.

Weakness

It has been observed that the ability of recovery patients to ask or request for nurse help after the procedure have less energy and are physically weaker, either due to medication or the procedure itself. Because there is no designated pre or post area, recovery patients who are away from the nurse station (such as the red areas in this design) will have a harder time contacting nurses for emergencies or requests, unless nurses constantly periodically check-up.

Alternative Layout 2-Maximize Overall Capacity

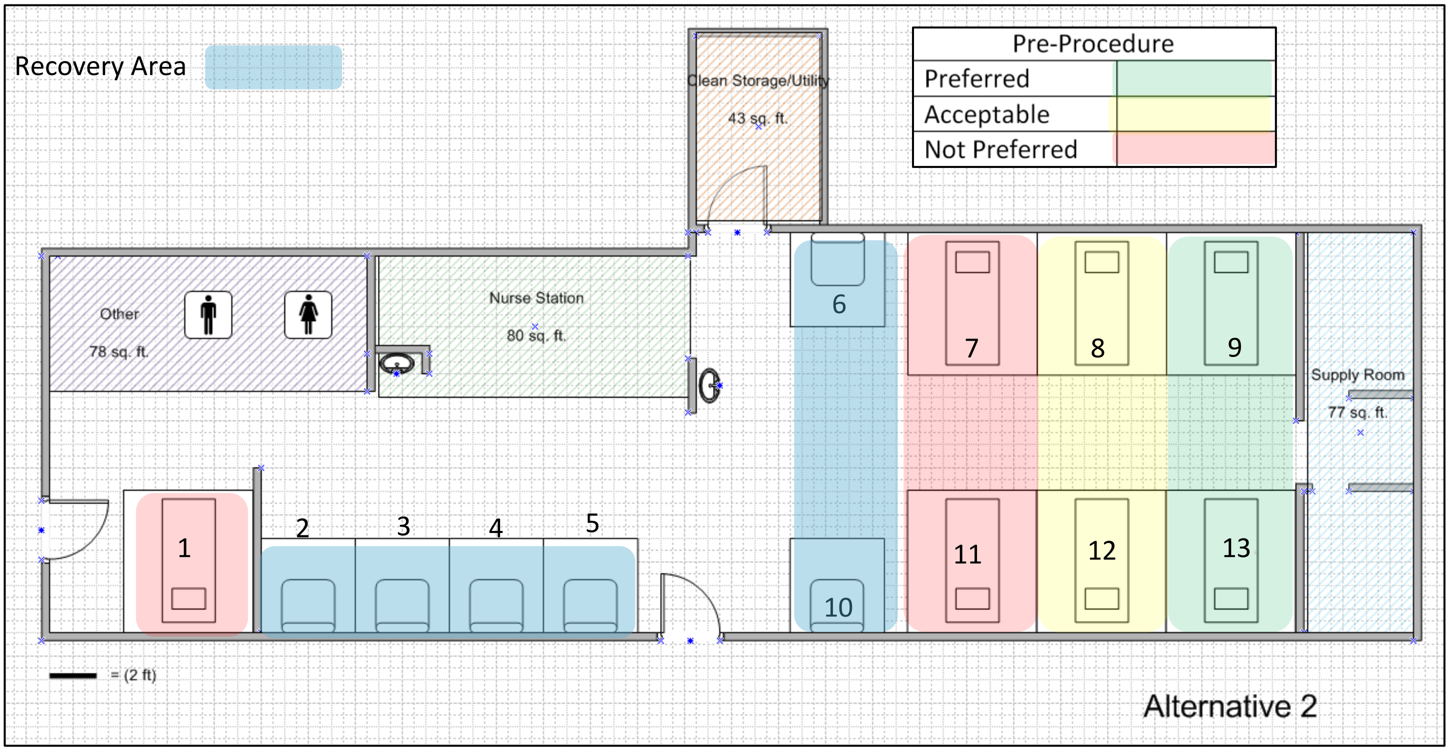


Figure 20 Alternative 2-Maximum Capacity

This layout maximizes overall capacity. With 7 beds and 6 chairs, the total holding capacity for patients is maximized to 13. The chairs are mainly for recovery patients while the beds are for prepping patients before the procedure. This distinction allows for a natural division between the pre-procedure and recovery area. The supply room and clean storage unit are swapped to minimize overall nurse workflow movement. This allows for a more concentrated flow.

Expected Workflow Distance

Bed position #8 was used to calculate the expected workflow distance for pre-procedure. The expected distance for nurses to travel on a given patient was calculated to be approximately 746 feet. The increase of nurse movement compared to alternative 1 was mainly due to the increase distance from the pre-procedure area to the nurse station.

Cost Analysis of Workflow Movement

Cost was calculated by movement and nurse hourly wage with the assumption that a nurse walks 3 mph. Daily cost and yearly cost was then calculated by the average number of patients per day or patients seen in an entire year. See Appendix L for detailed movement and cost calculation.

Table 5 Alternative 2 Cost Workflow Movement Analysis

Movement per patient	746 ft
Nurse hourly wage	$35
Estimate Daily Cost	$34
Estimate Yearly Cost	$8,900

Qualitative Analysis

Strengths

This layout maximizes a balance holding capacity for patients who are prepping for the procedure and those who are recovering. The distinction between a pre-procedure area and a post recovery allows for a concentrated workflow for both types of patients. Since the chairs are positioned near the nurse station, this allows nurses to closely monitor the recovery patients. Recovery patients also benefit by being close to the nurse station because the close proximity allows personal requests to be heard right away without having to vocally project across the room or use more energy.

Weakness

Nurses who are attending pre-procedure patients are positioned farthest away from the nurse's station. If phone calls, office supplies, or a workstation needs to be used, the nurse must travel across the staging facility which can take up time and energy. Bathrooms are also located on the other end of the facility for staging patients. Also in order to implement this design, there is more logistics that need to be planned to transfer a patient from a status of pre-procedure to recovery.

Alternative Layout 3-Most Efficient Staging Area

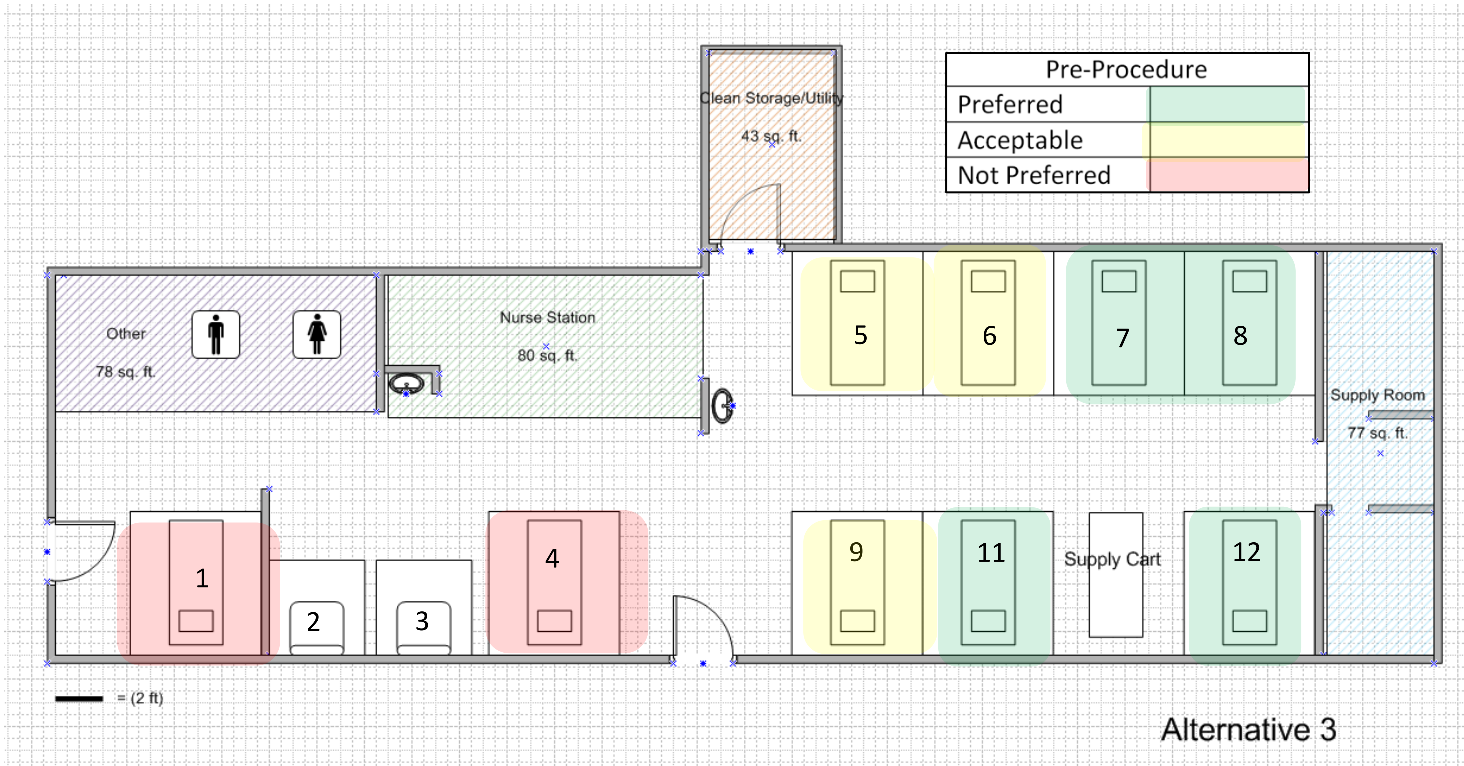


Figure 21 Alternative 3-Efficient Staging

This layout seeks to minimize nurse staging movement by maximizing movement efficiency. There are 9 beds and 2 chairs for a total holding capacity of 11 patients. The two chairs are mainly a recovery option, while the beds can be used for pre or post procedure. In this design there is a supply cart that will supply the thermometer, stethoscope, trash bin, and gloves. This will minimize the amount of trips nurses will have to make to the nurse station or supply room. No beds are designated to be solely pre-procedure or recovery, however it would be beneficial if beds #4 and #5 were used as recovery and beds #10, #7, #8 and #11 were used as pre-procedure.

Expected Workflow Distance

Bed position #6 was used to calculate the expected workflow distance for pre-procedure. The expected distance for nurses to travel on a given patient was calculated to be approximately 408 feet. The decrease of nurse movement compared to alternative 1 and 2 was mainly due to the decrease distance to trash and gloves by the supply cart. See Appendix X for detail calculation.

Cost Analysis of Workflow Movement

Cost was calculated by movement and nurse hourly wage with the assumption that a nurse walks 3 mph. Daily cost and yearly cost was then calculated by the average number of patients per day or patients seen in an entire year. See Appendix M for detailed movement and cost calculation.

Table 6 Alternative 3 Cost Workflow Movement Analysis

Movement per patient	408 ft
Nurse hourly wage	$35
Estimate Daily Cost	$19
Estimate Yearly Cost	$4,900

Qualitative Analysis

Strengths

This layout minimizes workflow movement by reducing the distance of trips necessary to prepare a patient. The location of the supply cart acts as central location for common items and materials. This layout also allows for a concentrated nurse workflow for pre-procedure patients, and recovery patients can still be located near the nurse station.

Weakness

The placement of the supply cart takes away one potential bed or chair. Also once again, nurses who are attending pre-procedure patients are positioned farthest away from the nurse's station which may result to more energy expended to retrieve a phone call or fax. With the presence of a supply cart, it might decrease the level the "cleanness" of the layout perceived by the patient.

Recommend Design

The alternative designs will be proposed to the hospital for which design to be implemented. The hospital will weigh the strengths and weakness of each design according to their criteria and goals. Depending on the weight or criteria, the hospital will select a design and if necessary make modifications.

Recommendations and Conclusion

It was discovered that the largest non-value added time in Cardiac Staging was waiting to transfer into the Cath Lab. Waiting time acuminated to 60% of all the time spent in Cardiac Staging. With a skewed right distribution, delays, unexpected procedure durations, and schedule changes all contribute to long staging durations. However, it was found that proper scheduling can help reduce over waiting time and minimize delay impacts.

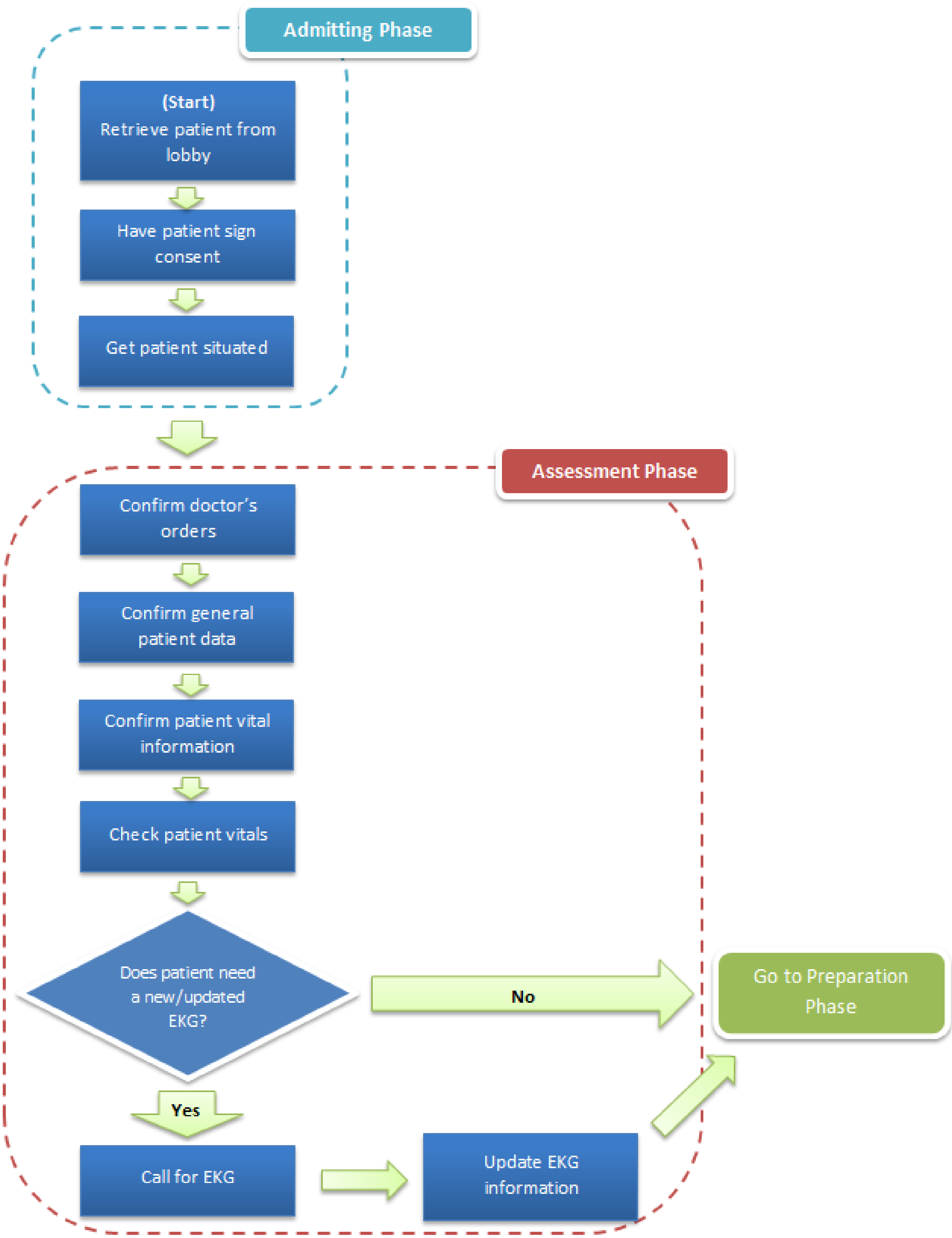
The first recommendation to decrease waiting time is to have patients arrive one hour and fifteen minutes before their procedure. This will allow nurses ample time to prepare patients and also receive lab reports back if they ordered one. Also, it is very common for most the procedures to last longer than an hour. Combine with the time it takes to turn over the Cath Lab, one hour and fifteen minutes is a reasonable amount of time for nurses to prepare patients. Patients will also benefit from not having to wait too long before the procedure, but also not feel rush to transfer into the Cath Lab. The second recommendation is to schedule patients by the shortest procedure duration first. The SPR rule minimizes queue time because it reduces the time waiting for the previous procedure to end. Another added benefit to implementing the SPR rule is that it enables a more level workload for the Cardiac Staging nurses rather than dealing with irregular procedure scheduling. Due to the number of different procedures and variations within each procedure, it was not possible to capture every procedure and its variation. If a procedure wasn't captured in this study, a general data point can be assigned to its procedure category. See Appendix I.

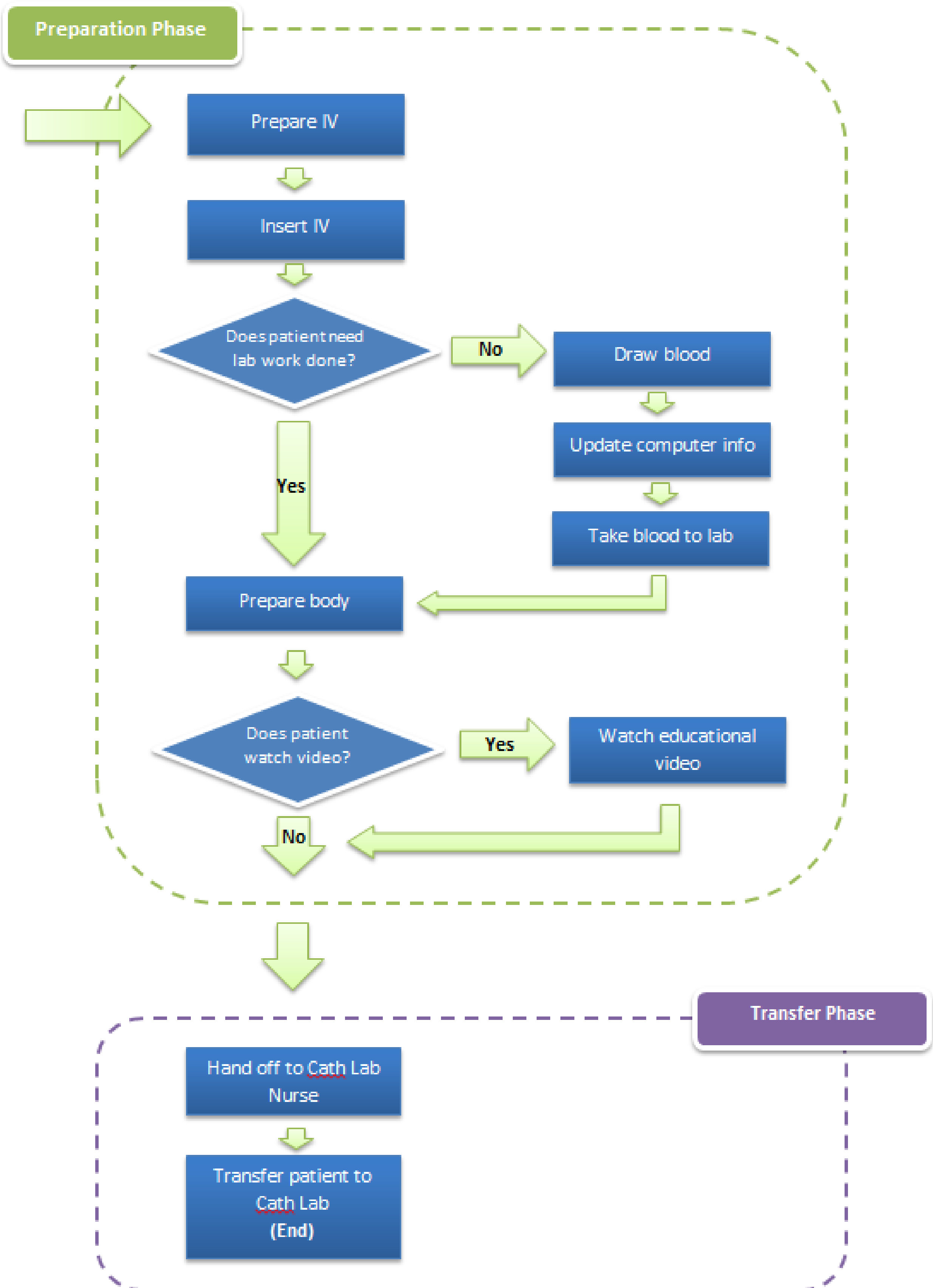
To implement the scheduling recommendations, it is advised to slowly implement these changes over time rather than all at once. Have patients who are scheduled last arrive an hour and fifteen minutes before the scheduled procedure in order to decrease the possibility of delaying patients who are behind them if nurses need more than one hour and fifteen minutes to prepare them. Once the staging nurses have confidence they can prepare patients within an hour and fifteen minutes then slowly schedule more patients to arrive at one hour and fifteen minutes until all the hospital staff in the system is comfortable with the new change. This will also allow time to work out any unforeseen problems or obstacles in preparing patients within an hour and fifteen minutes. In the same way, apply the SPR once a week to see if there are any noticeable reduced waiting times for patients. Once again, the SPR is most effective when there are a three or more patients who have different priority numbers.

The design of the new Cardiac Staging area sought to increase holding capacity while allowing for a smooth workflow. While the goal is to increase holding capacity, the ultimate goal of why the hospital is increasing the size of staging is to ultimately increase patient throughput. It must be noted however, that increasing the holding capacity of staging will not result to an increase of patient throughput directly. It is observed that the Cath Lab is the bottleneck and to increase patient throughput, the hospital must increase capacity of its Cath Lab. If the Cath lab does not increase its capacity, the hospital will be losing more money because the new staging facility will increase cost and operational expenses.

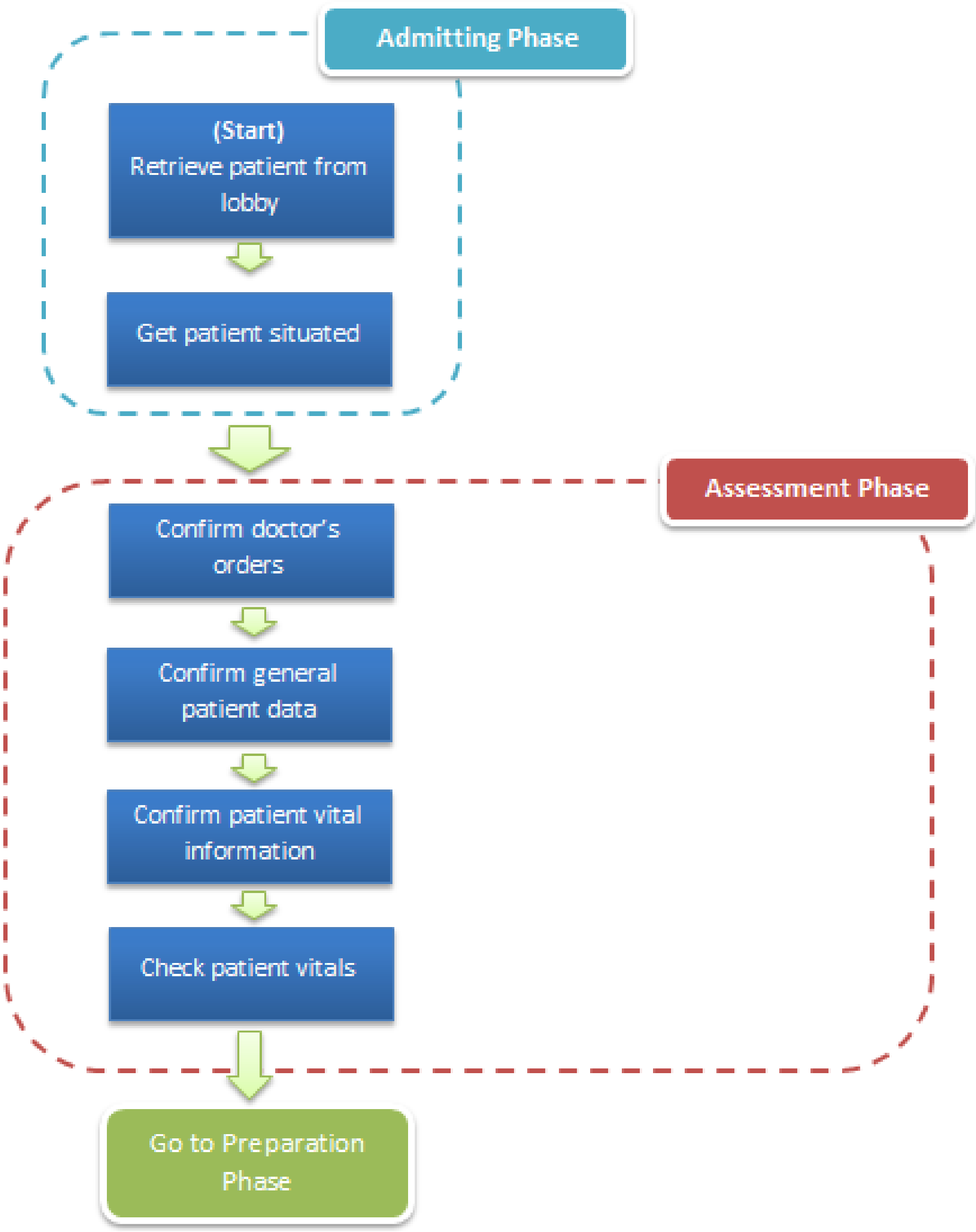
Appendix

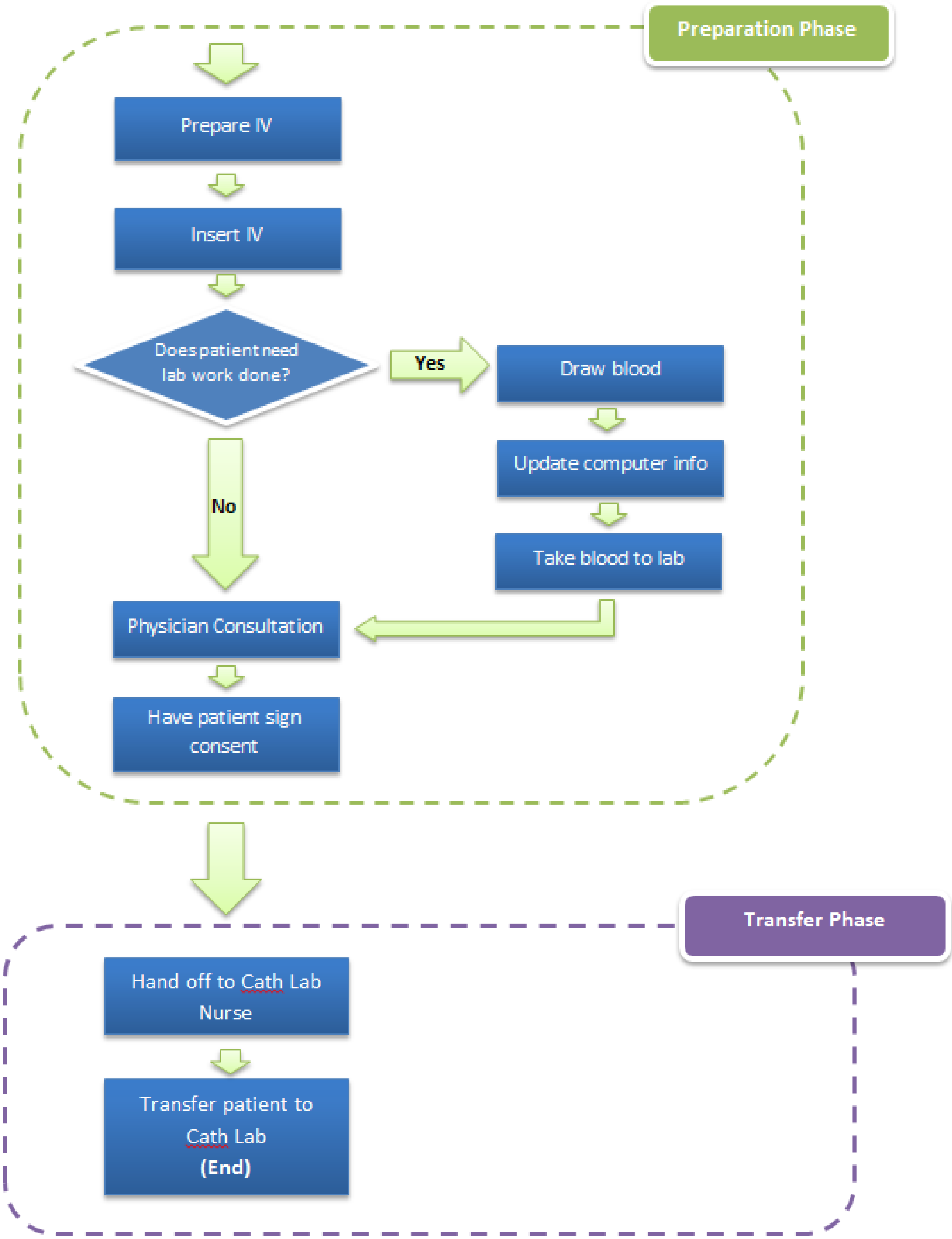
Appendix A: Cardiac Nurse Staging Process Flow Chart for Cardiac Procedures




Preparation Phase
Prepare IV
Insert IV
Does patient need lab work done?
No
Draw blood
Update computer info
Take blood to lab
Yes
Prepare body
Does patient watch video?
Yes
Watch educational video
No
Transfer Phase
Hand off to Cath Lab Nurse
Transfer patient to Cath Lab (End)

Appendix B: Cardiac Nurse Staging Process Flow Chart for IR Procedures




Preparation Phase
Prepare IV
Insert IV
Does patient need lab work done?
Yes
Draw blood
Update computer info
Take blood to lab
No
Physician Consultation
Have patient sign consent
Transfer Phase
Hand off to Cath Lab Nurse
Transfer patient to Cath Lab
(End)

Appendix C: Cardio vs. IR Patient Staging Duration

```
Variable  Type      N  N*    Mean  SE Mean  StDev  Minimum      Q1  Median
C.S.      CDL     184   3  149.64     6.62  89.74    15.00   95.00  120.00
          IR       54   4  144.63     8.45  62.12    10.00  105.00  137.50
```

Two-Sample T-Test and CI

```
Sample    N   Mean  StDev  SE Mean
1       184  149.6   89.7      6.6
2        54  144.6   62.1      8.5


Difference = mu (1) - mu (2)
Estimate for difference:  5.0
95% CI for difference:  (-16.2, 26.3)
T-Test of difference = 0 (vs not =): T-Value = 0.47  P-Value = 0.641  DF = 124
```

Since the P-value is .641, we do not have enough evidence that Cardio and IR patient duration is different.

Appendix D: Descriptive Statistics for Procedure Duration

Descriptive Statistics: Procedure Duration

Variable	procedure	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Proc.Duration	Angio	11	4	130.0	15.3	50.8	60.0	80.0	120.0	175.0	215.0
	Bivent defib	3	0	145.0	13.2	22.9	120.0	120.0	150.0	165.0	165.0
	Bivent gen	2	4	110.00	5.00	7.07	105.00	*	110.00	*	115.00
	Bivent Pacer	2	1	118.0	18.0	25.5	100.0	*	118.0	*	136.0
	Cardiover	29	4	60.10	4.55	24.50	33.00	45.00	55.00	70.00	160.00
	Cath place	1	0	90.000	*	*	90.000	*	90.000	*	90.000
	CT Biopsy	17	3	62.06	5.20	21.44	35.00	45.00	55.00	72.50	115.00
	Dialysis Cath	3	2	73.67	8.17	14.15	65.00	65.00	66.00	90.00	90.00
	Drain removal	0	1	*	*	*	*	*	*	*	*
	Drain tube	0	1	*	*	*	*	*	*	*	*
	Dual Chamber	26	5	101.00	4.43	22.60	65.00	85.00	91.00	121.25	150.00
	Evac hem.	1	0	100.00	*	*	100.00	*	100.00	*	100.00
	Fistula	4	2	135.0	32.9	65.7	60.0	70.0	142.5	192.5	195.0
	HC	21	4	104.19	4.41	20.20	75.00	86.00	105.00	117.50	150.00
	Implanted port	1	1	151.00	*	*	151.00	*	151.00	*	151.00
	IVC filter	2	1	68.50	6.50	9.19	62.00	*	68.50	*	75.00
	LHC	34	14	102.91	6.37	37.15	60.00	75.00	90.00	117.50	217.00
	Loop	6	0	78.7	11.8	29.0	45.0	56.3	70.0	110.3	120.0
	Lumbar	11	1	52.73	5.43	18.02	23.00	45.00	55.00	60.00	85.00
	Pace upgrade	1	1	248.00	*	*	248.00	*	248.00	*	248.00
	Pacemaker Gen exchange	1	0	141.00	*	*	141.00	*	141.00	*	141.00
	RHC	1	0	185.00	*	*	185.00	*	185.00	*	185.00
	Single chamber	4	0	68.00	5.35	10.71	54.00	57.50	69.00	77.50	80.00
	TEE	8	1	112.5	37.3	105.6	40.0	66.3	85.0	93.8	370.0
	Tube Place	2	0	102.5	27.5	38.9	75.0	*	102.5	*	130.0
	Venogram	0	1	*	*	*	*	*	*	*	*
	VERT.	2	2	105.50	0.500	0.707	105.00	*	105.50	*	106.00

Appendix E: Recovery Duration by Procedure

Descriptive Statistics: Recovery

Variable	procedure	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Recovery	Angio	7	8	292.1	49.3	130.5	85.0	210.0	305.0	400.0	475.0
	Bivent defib	3	0	203.3	42.8	74.2	140.0	140.0	185.0	285.0	285.0
	Bivent gen	1	5	350.00	*	*	350.00	*	350.00	*	350.00
	Bivent Pacer	1	2	110.00	*	*	110.00	*	110.00	*	110.00
	Cardiover	24	9	109.2	31.2	153.1	40.0	62.8	67.5	83.8	800.0
	Cath place	1	0	90.000	*	*	90.000	*	90.000	*	90.000
	CT Biopsy	12	8	155.0	13.4	46.5	40.0	140.0	157.5	180.0	240.0
	Dialysis Cath	3	2	71.7	28.0	48.6	30.0	30.0	60.0	125.0	125.0
	Drain removal	0	1	*	*	*	*	*	*	*	*
	Drain tube	0	1	*	*	*	*	*	*	*	*
	Dual Chamber	10	21	123.5	18.0	56.8	15.0	96.3	125.0	158.8	210.0
	Evac hem.	1	0	210.00	*	*	210.00	*	210.00	*	210.00
	Fistula	1	5	105.00	*	*	105.00	*	105.00	*	105.00
	HC	17	8	271.9	26.4	108.7	78.0	182.5	240.0	372.5	440.0
	Implanted port	0	2	*	*	*	*	*	*	*	*
	IVC filter	2	1	65.0	40.0	56.6	25.0	*	65.0	*	105.0
	LHC	19	29	238.5	21.9	95.5	157.0	190.0	200.0	250.0	475.0
	Loop	4	2	77.5	15.5	31.0	50.0	52.5	70.0	110.0	120.0
	Lumbar	10	2	61.00	9.63	30.44	25.00	35.00	52.50	80.00	125.00
	Pace upgrade	0	2	*	*	*	*	*	*	*	*
	Pacemaker Gen exchange	0	1	*	*	*	*	*	*	*	*
	RHC	1	0	120.00	*	*	120.00	*	120.00	*	120.00
	Single chamber	2	2	155.0	10.0	14.1	145.0	*	155.0	*	165.0
	TEE	9	0	123.2	46.7	140.0	60.0	60.0	75.0	112.0	490.0
	Tube Place	2	0	82.5	27.5	38.9	55.0	*	82.5	*	110.0
	Venogram	0	1	*	*	*	*	*	*	*	*
	VERT.	1	3	99.000	*	*	99.000	*	99.000	*	99.000

Appendix F: Cardiac Staging Time Studies

Cardiac Patient Observations

A total of 10 cardiac patients was observed going through Cardiac Staging. Some element times could not be established as sometimes nurses execute several elements simultaneously making it difficult to record individual element times. In some cases, abstraction was used to record the overall phase time. These averaged times were verified by the staging staff.

Overall Time (OT)

OT = Element Cum + General

Admitting

	Retrieve	Consent	Situated	Element Cum	General	OT Admitting
Run 1				0.00	12.00	12.00
Run 2	13.22	2.73	1.90	17.85		17.85
Run 3				0.00	9.27	9.27
Run 4	6.25	5.30	6.35	17.90		17.90
Run 5				0.00	18.57	18.57
Run 6				0.00	7.80	7.80
Run 7				0.00	31.15	31.15
Run 8			9.28	9.28	3.97	13.25
Run 9				0.00	8.58	8.58
Run 10		10.9		10.90	10.28	21.18
					Avg OT	**15.76**

Assessment Phase

	Confirm Data	EKG	Check Vitals	Element Cum	General Asses	OT Assess
Run 1		4.22		4.22	4.18	8.40
Run 2	6.42		2.10	8.52	10.73	19.25
Run 3		2.13		2.13	24.02	26.15
Run 4				0.00	34.45	34.45
Run 5		2.88		2.88	10.23	13.11
Run 6				0.00	14.17	14.17
Run 7		2.90		2.90	33.93	36.83
Run 8				0.00	8.88	8.88
Run 9				0.00	1.90	1.90
Run 10	5.03	5.22	2.75	13.00		13.00
					Avg OT	**17.61**

Preparation Phase

	IV	Prepare Body	Video	Element Cum	General Prep	OT Preparation
Run 1	11.83	13.02	15.00	39.85		39.85
Run 2	9.88	8.15	15.00	34.96	5.95	40.91
Run 3	7.00			7.00	3.15	10.15
Run 4				0.00	16.18	16.18
Run 5	10.00			10.00	6.95	16.95
Run 6				0.00	32.50	32.50
Run 7				0.00	21.53	21.53
Run 8*				0.00		
Run 9*				0.00		
Run 10		13.83		13.83		13.83
*Pat. not prep					**Avg OT**	**23.99**

Transfer Phase

	Wait Time	Transfer	Element Cum	General Trans	OT Transfer
Run 1	74.67		0.00	80.67	80.67
Run 2	201.38		0.00	207.38	207.38
Run 3	55.00		0.00	61.00	61.00
Run 4	118.75	3.30	124.75		124.75
Run 5	52.94	1.97	58.94		58.94
Run 6	25.00		0.00	31.00	31.00
Run 7	57.00		0.00	63.00	63.00
Run 8*	57.50	2.78	63.50		63.50
Run 9*	96.32	3.32	102.32		102.32
Run 10	181.50			187.5	187.50
Run 11	65.20				71.20
				Avg OT	**95.57**

IR Patient Observations

IR Admitting

	Retrieve	Situated	Element Cum	General Admit	OT Admitting
Run 1			0.00	17.00	17.00
Run 2	13.62	8.45	22.07		22.07
				Avg OT	**19.54**

Assessment Phase

	Confirm Data	Check Vitals	Element Cum	General Asses	OT Assess
Run 1			0.00	4.18	4.18
Run 2			0.00	7.25	7.25
				Avg OT	**5.72**

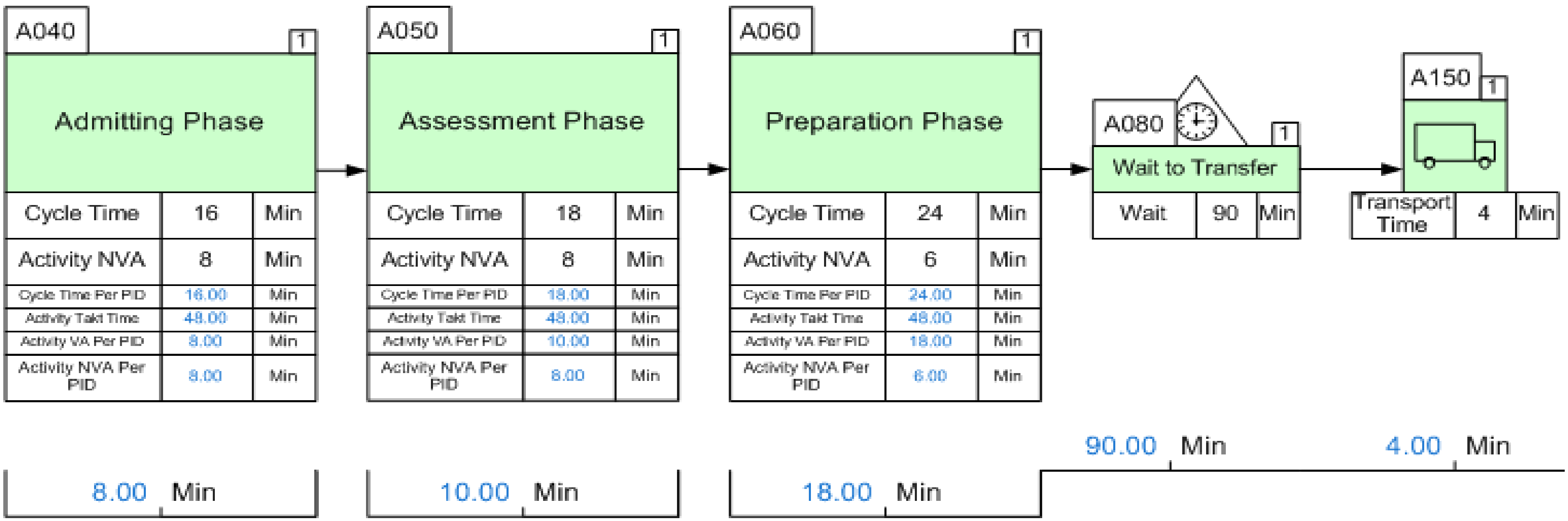
Preparation Phase

	IV	Wait for Physcian	Physcian Consult	Consent	Element Cum	General Prep	OT Preparation
Run 1			4.00		4.00	39.00	43.00
Run 2	8.07	111.72	10.45	3.95	134.19	5.95	140.14
						Avg OT	**91.57**

Transfer to Cath lab

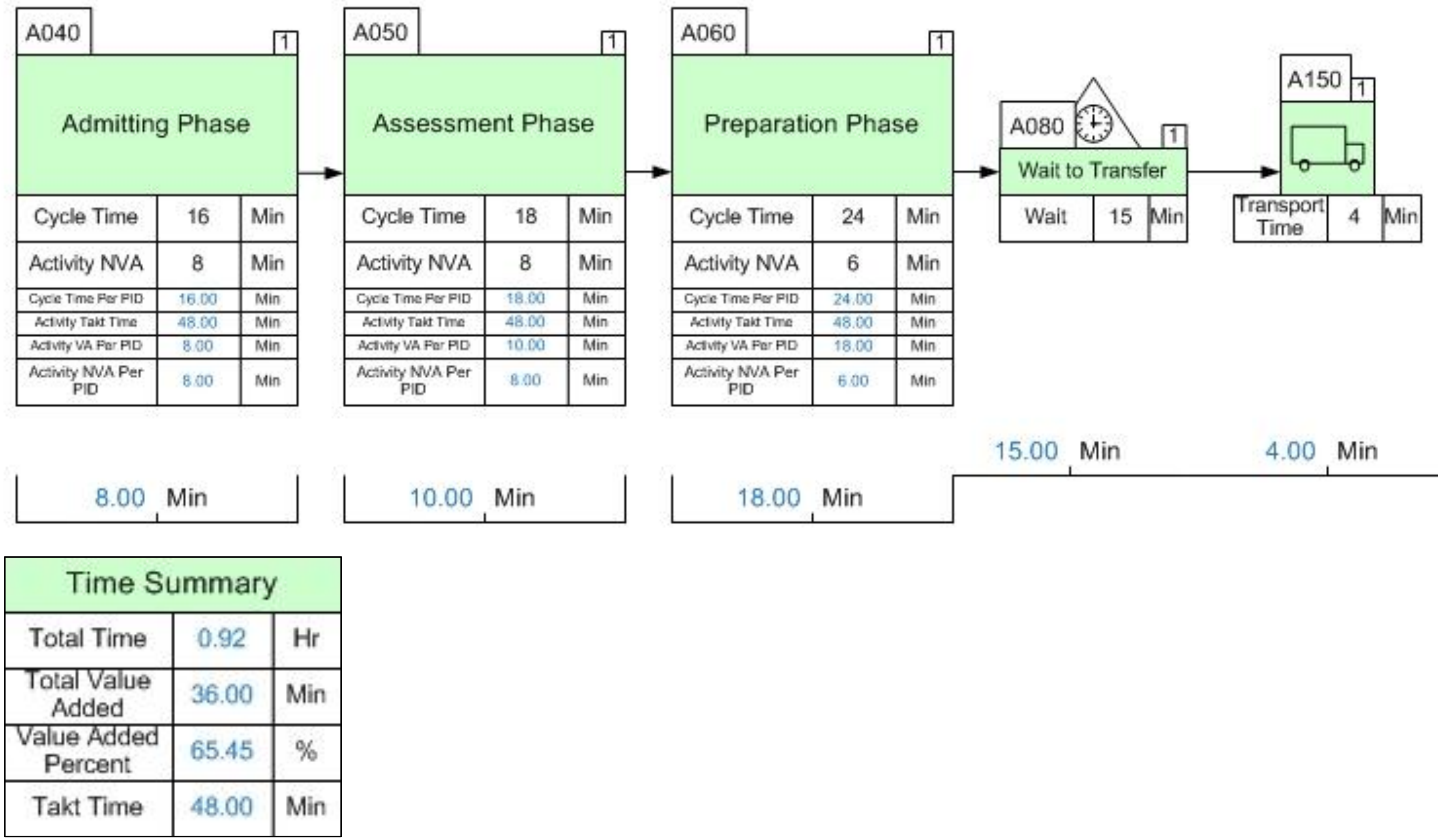
	Wait	Transfer	Element Cum	General Trans	OT Transfer
Run 1			0.00	12.00	12.00
Run 2	1.42		1.42		1.42
				Avg OT	**6.71**

Appendix G: Current Value Stream Map



Time Summary		
Total Time	2.53	Hr
Total Value Added	36.00	Min
Value Added Percent	23.68	%

Appendix H: Future Value Stream Map



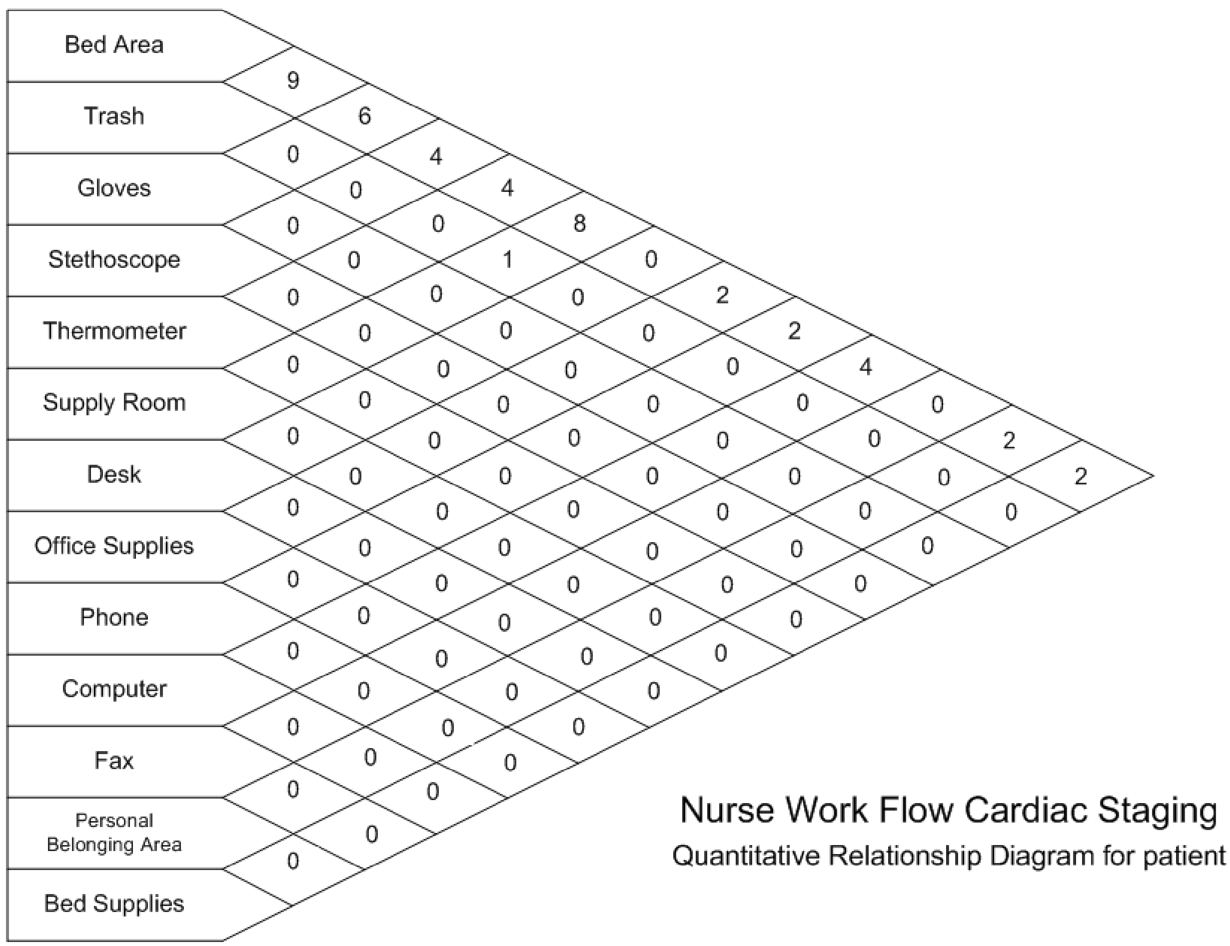
Appendix I: Procedure Priority List

All procedures that was recorded twice or more were given a priority type. Due to the many types of procedures and their variations, it was impossible to capture every procedure. If any procedure is not listed, there is an option to use the priority type underneath **General.**

Procedure	Samples Size	Median (min)	Std. Dev	Type
CardioVersion	29	55	24.5	1B
CT Biospy	17	55	21	1B
Lumbar	11	55	18.02	1B
Declot Dialysis	3	66	14	2A
IVC filter	2	68.5	9.19	2A
Single Chamber	4	69	10.71	2A
Loop	6	70	29	2B
TEE	8	85	19.24	2B
Cath Placement	1	90		3X
LHC	34	90	37.15	3C
Dual Chamber	26	91	22.6	3B
Evac Hem	1	100		3X
Tube Place	2	102	38.9	3C
HC	21	105	20.2	3B
Vert.	2	106	0.707	3A
Bivent Gen	2	110	7.07	3A
Bivent Pacer	2	118	26	3B
Angio	11	120	50.8	4C
Pace Gen exchange	1	141		4X
Fistula	4	142.5	65.7	4C
Bivent defib	3	150	22.9	4B
Implatned Port	1	151		4X
RHC	1	185		5X
Pace Upgrade	1	248		5X
General				
Cardiac Pacer	39	99	35.36	3B
Cardio Invasive	73	99	38	3C
Cardio Non-Invasive	37	63	56	2C
IR	44	65	34	2C

Appendix J: Quantitative Relationship Diagram

This diagram shows the number of trips a nurse takes between a certain area or object while preparing a patient for procedure. As shown below, most the movement occurs along the Bed Area grid, indicating that the bed area is the central location in which all movement centers around.



Appendix K: Alternative 1 Nurse Workflow Movement and Cost Calculation

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Distance (Feet)													
2		Bed Area	Trash	Gloves	Steth.	Therm.	Supply Room	Desk	Office Supply	Phone	Computer	Fax	Belongings	Bed Supplies
3	Bed Area	0	8	8	12	12	15	27	27	21	14	27	16	27
4	Trash	8	0				2							
5	Gloves													
6	Steh.													
7	Therm.													
8	Prep Room		2											
9	Desk													
10	Office Supply													
11	Phone													
12	Computer													
13	Fax													
14	Personal Belonging													
15														
16		Distance Cum:		72	48	48	48	120	0	54	42	56	32	54
17		Labor Cost:		30	32	35	37	40						
18		Movement (ft per hour):		3072	(3 mph)									
19														
20		Distance Total:		574										
21		Movement duration(hrs)		0.186848958										
22		Movement duration(min)		11.2109375										
23														
24		Cost per patient		$6.54										
25														
26		Daily Cost		$26.16										
27														
28		Estimate Yearly Cost		$6,801.30										

Appendix L: Alternative 2 Nurse Workflow Movement and Cost Calculation

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Distance (Feet)													
2		Bed Area	Trash	Gloves	Steth.	Therm.	Supply Room	Desk	Office Supply	Phone	Computer	Fax	Belongings	Bed Supplies
3	Bed Area	0	14	16	18	18	22	22	22	14	14	22	16	22
4	Trash	7	0				2							
5	Gloves													
6	Steh.													
7	Therm.													
8	Prep Room		2											
9	Desk													
10	Office Supply													
11	Phone													
12	Computer													
13	Fax													
14	Personal Belonging													
15														
16		Distance Cum:		126	96	72	72	176	0	44	28	56	32	44
17		Labor Cost:		30	32	35	37	40						
18		Movement (ft per hour):		3072	(3 mph)									
19														
20		Distance Total:		746										
21		Movement duration (hrs)		0.242838542										
22		Movement duration(min)		14.5703125										
23														
24		Cost per patient		$8.50										
25														
26		Daily Cost		$34.00										
27														
28		Estimate Yearly Cost		$8,839.32										
29														

Appendix M: Alternative 3 Nurse Workflow Movement and Cost Calculations

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Distance (Feet)**													
2		**Bed Area**	**Trash**	**Gloves**	**Steth.**	**Therm.**	**Supply Ro**	**Desk**	**Office Supply**	**Phone**	**Computer**	**Fax**	**Belongings**	**Bed Supplies**
3	**Bed Area**	0	4	5	5	5	15	12	12	12	12	12	16	27
4	**Trash**	8	0				2							
5	**Gloves**													
6	**Steh.**													
7	**Therm.**													
8	**Prep Room**		2											
9	**Desk**													
10	**Office Supply**													
11	**Phone**													
12	**Computer**													
13	**Fax**													
14	**Personal Belonging**													
15														
16		**Distance Cum:**		36	30	20	20	120	0	24	24	48	32	54
17		**Labor Cost:**		30	32	35	37	40						
18		**Movement (ft per h**		3072	(3 mph)									
19														
20		**Distance Total:**		408										
21		**Movement duration**		0.1328125										
22		**Movement duration**		7.96875										
23														
24		**Cost per patient**		$4.65										
25														
26		**Daily Cost**		$18.59										
27														
28		**Estimate Yearly Cost**		$4,834.38										
29														

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